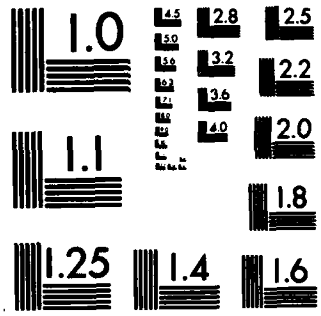
AD-A140 053 COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT 1/1
USER'S GUIDE COMPUTE..(U) ARMY ENGINEER WATERWAYS
EXPERIMENT STATION VICKSBURG MS J M FERRITTO ET AL.
UNCLASSIFIED JAN 84 WES-IR-K-84-2 F/G 13/13 NL

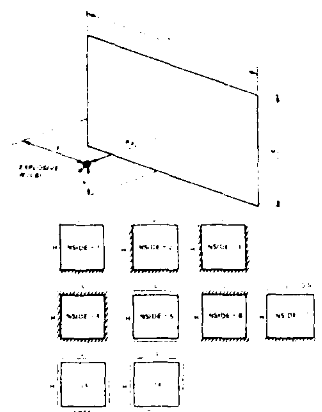
END
DATE
FILMED
5 84
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(12)

US Army Corps
of Engineers



COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

INSTRUCTION REPORT K-84-2

AD A140053

USER'S GUIDE: COMPUTER PROGRAM FOR OPTIMUM DYNAMIC DESIGN OF NONLINEAR METAL PLATES UNDER BLAST LOADING (CSDOOR)

by

John M. Ferritto
Civil Engineering Laboratory
U. S. Navy Construction Battalion Center
Port Hueneme, Calif. 93043

Robert M. Wamsley
U. S. Army Engineer Division, Huntsville
Huntsville, Ala. 35807

Paul K. Senter
Automatic Data Processing Center
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

January 1984
Final Report

Approved For Public Release; Distribution Unlimited

Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

84 04 10 108

PROGRAM INFORMATION

Description of program

CSDOOR called X0057 in the Conversationally Oriented Real-Time Programming System (CORPS) library, is useful to perform rapid design of metal plates used to form the sides and roofs of blast cells and of metal used as doors--regular and built-up. The program may be used for any structural materials for which thé material properties are known, but steel is the most commonly used. The program may be used, with limitations, to optimize the design by finding the least-cost structures that satisfy all the design constraints.

Coding and data format

CSDOOR is written in FORTRAN and is operational on the following systems:

a. U. S. Army Engineer Waterways Experiment Station (WES) Honeywell DPS/1.

b. Office of Personnel Management Honeywell 6000 Series at Macon, Ga.

c. Control Data Corporation CYBERNET System, CYBER 170/760.

Data can be input either interactively from the user's terminal or from a prepared data file with line numbers. When data are input from the terminal during execution, the program provides prompting messages to indicate the type and amount of input data to be provided. Output can be obtained at the terminal, written to a permanent file for listing at the terminal at a later date, or directed to a mainframe line printer.

How To use CSDOOR

A short description of how to access the program on each of the three systems is provided below. It is assumed that the user knows how to sign on the appropriate system before trying to use CSDOOR. In the example initiation of execution commands below, all user responses are underlined, and each should be followed by a carriage return.

WES DPS/4 and Macon systems

After the user has signed on the system, the two system commands FORT and NEW get the user to the level to execute the program. Next, the user issues the run command

RUN WESLIB/CORPS/X0057,R

to initiate execution of the program. The program is then run as described in this user's guide. The data file should be prepared prior to issuing the RUN command. An example of initiation of execution is as follows, assuming a data file had previously been prepared:

```
HIS SERIES 6ØØ ON 10/17/83 AT CHANNEL 5647
USER ID - RØKACASEMP
PASSWORD -
SYSTEM?  FORT NEW

0364200

COEWES HIS TIMESHARING ON 10/17/83 AT 10.328 CHANNEL 2244 TS1

USER ID --ROKAOMP
PASSWORD --

USERS = 043 TSS=145K  MEM-USED=38 SYS=0128K  PRO=2 000-WAIT-000K

*FORT NEW

READY

*RUN WESLIB/CORPS/XØØ57,R
```

CYBERNET System

The log-on procedure is followed by a call to the CORPS procedure file

```
OLD,CORPS/UN=CECELB
```

to access the CORPS library. The file name of the program is used in the command

```
BEGIN,CORPS,X0057
```

to initiate execution of the program. An example is:

```
83/10/17. 11.07.05. AA313IA
EASTERN CYBERNET CENTER SN487 NOS        1.4/531.281/18AD
FAMILY:  KOE
USER NAME:  CEROOO

TERMINAL:  515, NAMIAF
RECOVER/CHARGE:  CHARGE,CEROXXX,CEROOO
$CHARGE,CEROXXX,CEROOO

07.05.42. WARNING

ALL KOE USERS PLZ TYPE EXPLAIN,RBF,CONFIG.
```

```
C>OLD,CORPS/UN=CECELB
C>BEGIN,,CORPS,X0057
```

How To Use CORPS

The CORPS system contains many other useful programs which may be catalogued from CORPS by use of the LIST command. The execute command for CORPS on the WES and Macon systems is:

```
RUN WESLIB/CORPS/CORPS,R
ENTER COMMAND (HELP,LIST,BRIEF,MESSAGE,EXECUTE,OR STOP)
*?LIST
```

on the Boeing system, the commands are:

```
OLD,CORPS/UN=CECELB
ENTER COMMAND (HELP,LIST,BRIEF,MESSAGE,EXECUTE,OR STOP)
*?LIST
```

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Instruction Report K-84-2

2. GOVT ACCESSION NO.: AD-A140053

3. RECIPIENT'S CATALOG NUMBER:

4. TITLE (and Subtitle): USER'S GUIDE: COMPUTER PROGRAM FOR OPTIMUM DYNAMIC DESIGN OF NONLINEAR METAL PLATES UNDER BLAST LOADING (CSDOOR)

5. TYPE OF REPORT & PERIOD COVERED: Final report

6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s): John M. Ferritto, Robert M. Wamsley, and Paul K. Senter

8. CONTRACT OR GRANT NUMBER(s):

9. PERFORMING ORGANIZATION NAME AND ADDRESS: Civil Engineering Laboratory, U. S. Navy Construction Battalion Center, Port Hueneme, Calif. 93043; U. S. Army Engineer Division, Huntsville, Huntsville, Ala. 35807; and Automatic Data Processing Center, U. S. Army Engineer Waterways Experiment Station, P. O. Box 631, Vicksburg, Miss. 39180.

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Computer-Aided Structural Engineering (CASE) Project

11. CONTROLLING OFFICE NAME AND ADDRESS: Office, Chief of Engineers, U. S. Army Washington, D. C. 20314

12. REPORT DATE: January 1984

13. NUMBER OF PAGES: 55

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):

15. SECURITY CLASS. (of this report): Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available from National Technical Information Service, Springfield, Va. 22151. This report was prepared under the Computer-Aided Structural Engineering (CASE) Project. A list of published CASE reports is printed on the inside of the back cover.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Blast Impulse Computation
CSDOOR
Dynamic Response Equation
Finite Element Analysis
Maximum Reaction (REA)
Objective Function
Plates
Structural Optimization
Unconstrained Minimization Approach

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

CSDOOR called X0057 in the Conversationally Oriented Real-Time Programming System (CORPS) library, is useful to perform roped design of metal plates used to form the sides and roofs of blast cells and of metal used as doors-regular and built-up. The program may be used for any structure materials for which the material properties are known but steel is the most commonly used. The program may be used, with limitations, to optimize the design by funding the least-cost structures that satisfies all the design constraints.

PREFACE

This user's guide documents a computer program called CSDOOR that can be used for optimum dynamic design of nonlinear metal plates subjected to blast (pressure-time) loading. CSDOOR is a modified version of a program called SDOOR that was written by Mr. John M. Ferritto, Civil Engineering Laboratory (CEL), U. S. Navy Construction Battalion Center, Port Hueneme, Calif. The SDOOR program was modified to include peak gas pressures used by the Huntsville Division (fig. 3-9 described in HNDM-1110-1-2) and to allow it to execute in a time-sharing mode with free-field input. The program is useful to perform rapid design of metal plates which function as sides and roofs of blast cells and those which serve as doors--regular and built-up. Detailed analysis and the fine points of design should be considered by other means. For example, design of connections should be in accordance with Huntsville Division Report HNDM-1110-1-2, "Suppressive Shields Structural Design and Analysis Handbook."

Funds for modification of the SDOOR program and preparation of this user's guide were provided to the Automatic Data Processing (ADP) Center, U. S. Army Engineer Waterways Experiment Station (WES), by the Office, Chief of Engineers (OCE), under the Computer-Aided Structural Engineering (CASE) Project.

The program was tested and recommended for Corps of Engineers' use by the CASE Task Group on Structures Subject to Explosion:

Mr. Robert Wamsley, Huntsville Division (Chairman)
Mr. Dennis Bellet, Sacramento District
Mr. John M. Ferritto, U. S. Navy Construction Battalion Center
Mr. Byron Foster, South Atlantic Division
Mr. William Gaube, Omaha District
Mr. William Hill, Middle East Division
Dr. Paul F. Mlakar, WES

Major parts of this user's guide are taken directly from Mr. Ferritto's original report on SDOOR (CEL Technical Note TN-1518). Mr. Wamsley and Mr. Paul K. Senter, ADP Center, WES, were responsible for the program modifications and wrote those parts of the report pertaining to the modifications. Dr. N. Radhakrishnan, Chief, ADP Center, WES, monitored the work, assisted by Mr. Senter. Mr. Seymour Schneider and, later, Mr. George Matsumura, Military Programs Directorate, were the OCE points of contact.

Commanders and Directors of WES during the period of development were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. Frederick R. Brown.

CONTENTS

LIST OF FIGURES

CONVERSION FACTORS, U. S. CUSTOMARY (NON-SI) TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary (NON-SI) units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
Fahrenheit degrees	5/9	Celsius degrees*
feet	0.3048	meters
inches	2.54	centimeters
pounds (force) per inch	1.75126850	newtons per centimeter
pounds (force) per square inch	6.89475789	kilopascals
pounds (mass)	0.45359237	kilograms
square feet	0.09290304	square meters

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$.

USER'S GUIDE: COMPUTER PROGRAM FOR OPTIMUM DYNAMIC DESIGN OF NONLINEAR METAL PLATES UNDER BLAST LOADING (CSDOOR)*

PART I: INTRODUCTION

Computer Program CSDOOR

1. Program CSDOOR was developed to perform rapid design of metal plates used to form the sides and roofs of blast cells and of metal plates used as doors. The program includes provisions for the use of plastic section modules for built-up doors, but optimization of such doors should not be performed because the weight-strength function is not defined. Nonhomogeneous door sections are not usually thought of as plates. However, for simplification, the term "plate" will be used throughout this guide to denote these sections, whether they be sides, roofs, walls, or built-up doors. Also, the program may be used for any structural material for which the material properties are known; however, because steel is more commonly used in construction, the word "steel" will be used in this guide.

Background of Original Computer Program (SDOOR) Development

2. The Department of Defense (DOD) has numerous facilities in which various types of explosives and munitions used by military services are produced. In most cases the production of ammunition utilizes assembly line procedures. Projectiles pass through various stages of preparation: filling with explosive, fuzing, marking, and packing. Hazardous operations, such as the filling of the projectile case with an explosive in a powder form and the compaction of the powder by hydraulic press, are accomplished in protective cells that are intended to confine the effects of an accidental explosion.

---

* CSDOOR is designated X0057 in the Conversationally Oriented Real-Time Program-Generating System (CORPS) library. Three sheets entitled "Program Information" have been hand-inserted inside the front cover of this report. They present general information on the program and describe how it can be accessed. If procedures used to access this and other CORPS library programs should change, recipients of this report will be furnished a revised version of the "Program Information."

3. Most of the existing production facilities were built in the 1940's. With few exceptions, the manufacturing technology and existing equipment represent the state of the art at that time. The production equipment was operated extensively during World War II, again during the Korean conflict, and recently during the Southeast Asia war. Much of this equipment and many of the structures housing it have been operating beyond their designed capacities.

4. DOD is conducting an ammunition plant modernization program intended to greatly enhance safety in the production plants by protective construction and automated processing and to reduce the number of personnel involved in hazardous operations (Mendolia 1973).

5. In 1969 Technical Manual 5-1300 (Departments of the Army, Navy, and Air Force 1969) was published to provide guidance to structural designers of munition plants. Specific objectives of the manual were to establish design procedures and construction techniques to (a) prevent propagation of explosions from one building (or part of a building) to another, (b) prevent mass detonations, and (c) protect personnel and equipment. The manual establishes blast-load parameters for designing protective structures and provides methods for calculating the dynamic response of steel plates. The design method accounts for close-in effects of a detonation with its associated high pressures and nonuniformity of loading on protective barriers.

6. A detailed method for assessing the degree of protection afforded by a protective facility did not exist prior to this manual's publication; consequently, the manual represents a significant improvement in design methods. The simplifications made in the development of the design procedures are presented in the manual. The analysis of a structure using the design procedure will generally result in a conservative estimate of the structure's capacity; therefore, structures designed using these procedures will generally be adequate for blast loads exceeding the assumed load conditions.

7. Even with the simplifications presented in TM 5-1300, the computational procedures are complex and time-consuming. An automated procedure was needed to enable structural designers to perform rapid analyses of the structural safety of blast-resistant walls and doors. The design parameters interact in a complex way since the procedure is both nonlinear and dynamic. From a design point of view, an optimization procedure was needed to minimize cost and maximize safety since blast-resistant construction has been reported

to cost three to five times as much as conventional construction. Therefore, the first objective was to automate the analysis procedures for determining the structural response of steel plates having a bilinear stiffness representation and subjected to blast shock and gas pressures. Plates are the basic elements forming sidewalls, roofs, floors, and doors of cells designed to confine the effects of accidental explosions. The second objective was to provide an optimum design procedure that will automatically produce a least-cost design for a given geometry as well as material properties and explosive weight for both feasible and nonfeasible starting points.

8. To meet these objectives, the U. S. Navy Construction Battalion Center developed a program SDOOR that automated the analysis procedures and optimized the design procedures (Ferritto 1977). However, additional modifications to the program were needed to include peak gas pressures, which are used by the U. S. Army Engineer Division Huntsville in design, and to allow the program to execute in a time-sharing mode with free-field input. Personnel of the U. S. Army Engineer Waterways Experiment Station, the Huntsville Division, and the U. S. Navy Construction Battalion Center collaborated to modify SDOOR--hence CSDOOR.

PART II: ANALYTICAL METHODS AND LIMITATIONS

9. In general, the analytical methods used in computer program CSDOOR follow those in TM 5-1300; consequently, the accuracy of both is the same. The methods are discussed in detail in TM 5-1300, TN 1494 (Ferritto 1977) and WES Instruction Report K-81-6, neither of which will be presented here. The CSDOOR solution of the dynamic response equation of motion has been found to agree very closely with the response chart of TM 5-1300. Additionally, the solution covers a wider range; thus it is more accurate in the areas not defined by the response chart. When the loading is less than one twentieth of the natural period, the response is determined by impulse equilibrium. The basic dynamic model in TM 5-1300 is limited to the primary response mode and does not consider higher modes.

10. The blast impulse computation is restricted to a wall geometry in which the height-to-length ratio is greater than 0.2. A modification was made by the Naval Surface Weapons Center to the original Picatinny Arsenal Program to remove several minor problem areas, such as the location of the charge. The blast impulse has all the limitations associated with the original Picatinny programs that are caused by limitations in the test data. It assumes the charge is an equivalent sphere of TNT. Shape effects, explosive equivalence, and explosive casings are considered, but only in an empirical manner as a result of limited available data.

PART III: STRUCTURAL OPTIMIZATION

11. The optimization problem consists of finding the least-cost structure that satisfies all the design constraints; or, stated in optimization terms, it consists of finding $\vec{X}$ such that $M(\vec{X})$ is a minimum and

$$g_i(\vec{X}) \leq 0 \qquad i = 1, 2, N$$

where

$\vec{X}$ = vector of design variables

N = number of design constraints

g = vector of design constraints

M = objective function

Specifically for this problem, the design variable selected is thickness of steel plate or section properties for a nonhomogeneous section. The design constraints are the flexural and shear limits. The objective function is the cost of the steel.

12. The fixed variables are

W = explosive weight

H = height

EL = length

h = height of explosive above floor

ℓ = distance of explosive from left side of wall

R_a = distance of explosive from wall

I = reflection code

f = dynamic yield stress

μ = ductility

13. The design parameter X is

X = t (thickness of plate)

14. The constraints g(X) are

$\delta(X) = \delta(\theta)$, maximum deflection

$t \geq 0.05$, minimum th[illegible]ss

$t \leq 20$, maximum th[illegible]

15. The methodology sel[illegible]he unconstrained minimization approach (Fox 1971 and Pope 1971[illegible] problem is converted to an unconstrained minimization by constructing a function ϕ of the general form

$$\phi(\vec{X},r) = M(\vec{X}) + P[g_1(\vec{X}), \ldots, g_n(\vec{X}), r]$$

For this problem the interior penalty function technique was selected. This methodology is suitable when gradients are not available, and, because the method uses the feasible region, a usable solution always results. The objective function is augmented with a penalty term that is small at points away from the constraints in the feasible region but increases rapidly as the constraints are approached. The form is as follows:

$$\phi(\vec{X},r) = M(\vec{X}) - r\sum_{j=1}^{N} \frac{1}{g_j(\vec{X})}$$

where M is to be minimized over all $\vec{X}$ satisfying $g(\vec{X}) < 0$, $j = 2$, $\ldots, N$. Note that if r is positive, then, since at any interior point all of the terms in the sum are negative, the effect is to add a positive penalty to $M(\vec{X})$. As the boundary is approached, some $g(\vec{X})$ will approach zero, and the penalty will increase rapidly. The parameter r will be made successively smaller in order to obtain the constrained minimum of M .

16. As stated above, the objective function (F) is the cost of the steel. Or

$$\text{Cost} = F = H \cdot EL \cdot t \cdot C$$

where C is the volumetric cost of material.

$$\phi = F + r\sum_{j=1}^{N} \frac{1}{g_j(\vec{X})}$$

where r is the penalty parameter.

17. The program requires a starting point in the feasible region before optimization can proceed. The program can automatically determine the starting point by incrementing the design variables until a feasible point is reached.

18. An algorithm which comprises the steps most commonly used is as follows:

<u>a</u>. Given a starting point X_o , satisfying all $g_j(\vec{X}) < 0$,

and an initial value for r, minimize ϕ to obtain X_{min}.

b. Check for convergence of X_{min} to the optimum.

c. If the convergence criterion is not satisfied, reduce r by $r \leftarrow rc$, where $c < 1$.

d. Compute a new starting point for the minimization, initialize the minimization algorithm, and repeat from step a.

The logic diagram for the interior penalty functions technique is shown in Figure 1.

19. The minimization for $\phi(\vec{X},r)$ shown in Figure 1 is accomplished by a method developed by Powell using conjugate directions (Fox 1971). Powell's method can be understood as follows: Given that the function has been minimized once in each of the coordinate directions and then in the associated pattern direction, discard one of the coordinate directions in favor of the pattern direction for inclusion in the next m minimizations, since this is likely to be a better direction than the discarded coordinate direction. After the next cycle of minimizations, generate a new pattern direction and again replace one of the coordinate directions. This process is illustrated in Figure 2.

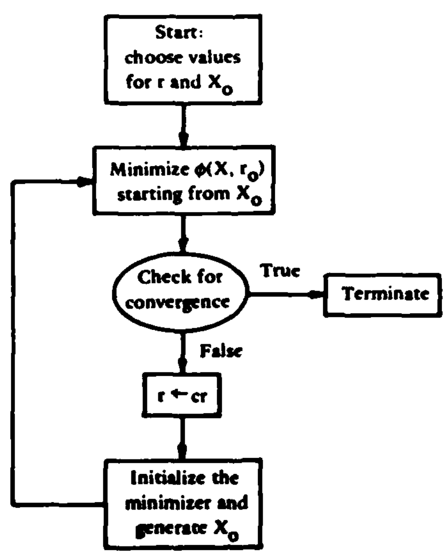


Figure 1. Logic diagram for interior penalty function technique

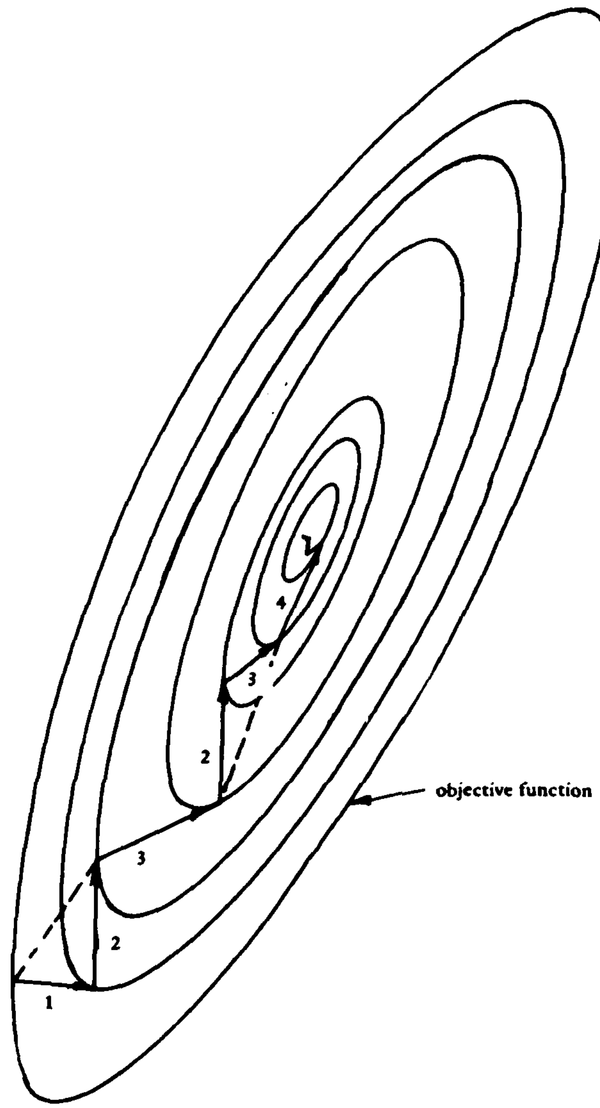


Figure 2. Step process, Powell method

20. Figure 3 is a logic diagram for the unconstrained minimization algorithm. The pattern move is constructed in block A, then used for a minimization step (blocks B and C), and then stored in S_n (block D) as all of the directions are up-numbered and S_1 is discarded. The direction S_n will then be used for a minimizing step just before the construction of the next pattern direction. Consequently, in the second cycle, both X and Y in block A are points that are minima along S_n , the last pattern direction.

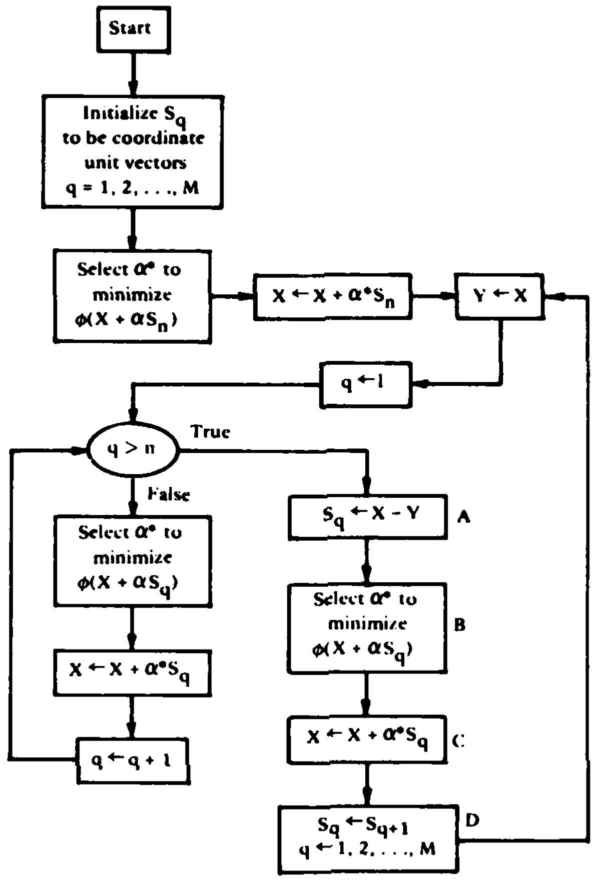
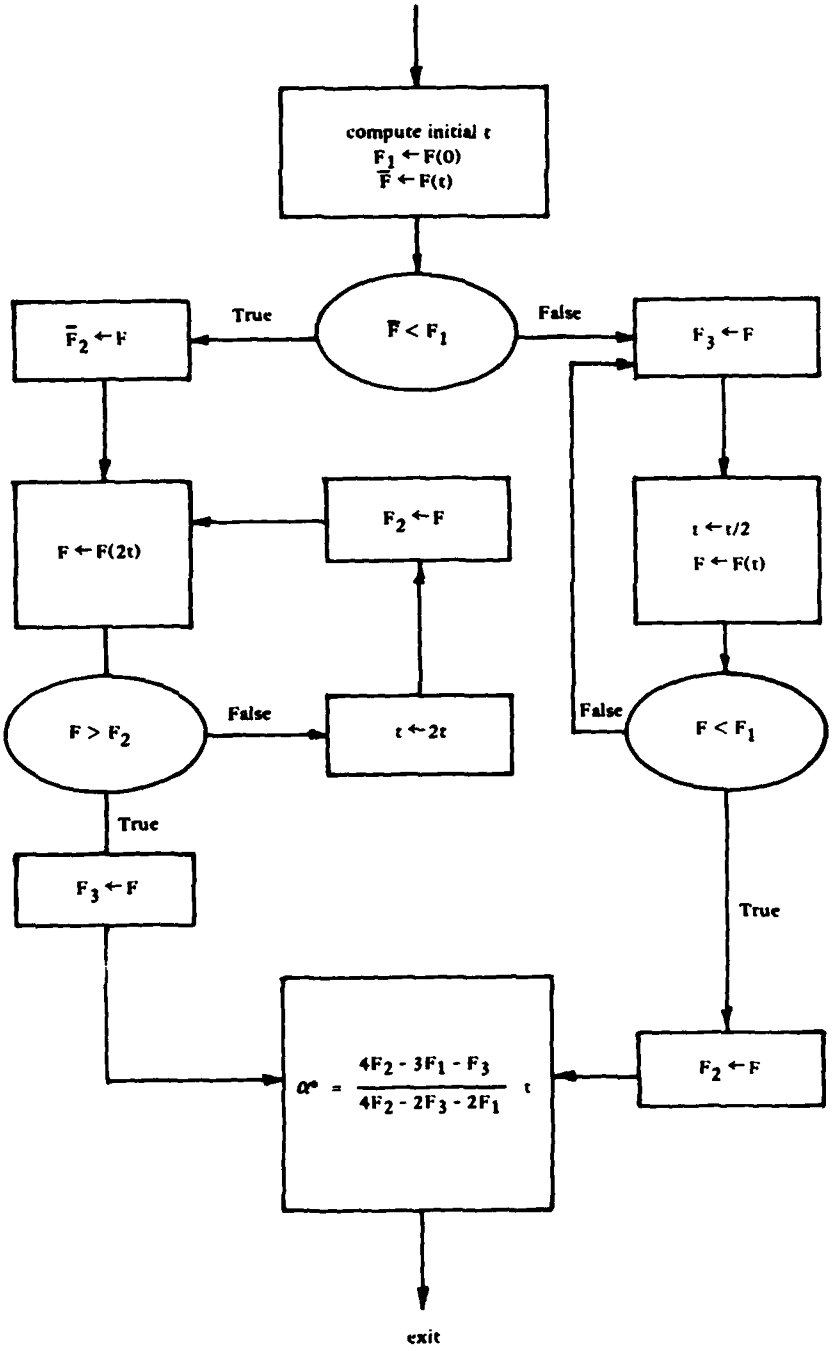


Figure 3. Logic diagram for minimization of $\phi(X)$

This sequence will impart special properties to $S_{n+1} = X - Y$ that are the source of the rapid convergence of the method.

21. Figure 3 shows a block requiring a one-dimensional minimization of α^* of the function $\phi(\vec{X} + \alpha^* S_q)$. The one-dimensional minimization uses a four-point cubic interpolation. It finds the minimum along the direction S_q , where $\vec{X}$ is the coordinate of the previous minimum. By trial and error it finds three points with the middle one less than the other two. It makes a quadratic interpolation and, then, a cubic interpolation. If the actual function evaluated at the new interpolated point is not sufficiently close to that of the preceding point, or if it is not sufficiently close to the interpolated function, then another cubic interpolation is made. The logic for this algorithm is shown in Figure 4.



satisfies $F_3 > F_1 > F_2$ or $F_1 > F_3 > F_2$

Figure 4. One-dimensional minimization algorithm

PART IV: APPROXIMATE COMPUTATION OF DOOR REACTION

22. It should be emphasized that this program is intended to assist in rapid approximate design and not detailed analysis. The basic procedures in TM 5-1300, TN-1494 and used herein have been found to be sufficiently accurate for simple geometries of beams and slabs without openings. Figures 5 and 6 compare deflections for a plate fixed on four sides and for a beam; the approximate solutions and the finite element solutions agree within about 10 percent. However, Figure 7 shows that the static shear procedures suggested in TM 5-1300 are substantially below dynamic shears; this is a limitation of the approximate procedures and is under current investigation.

23. A steel door attached to a concrete wall was examined using a finite element technique. Figure 8 shows the slab and door; Figure 9 shows the deflection of the door by the approximate procedure developed herein and the finite element procedure. There is some disagreement in deflection, especially when one considers the deflecting top support. It should be particularly noted that the deflecting support condition for actual doors on slabs (modeled correctly by finite element and assumed rigid by approximate solution) absorbs significant amounts of energy by rigid-body/door motion. Thus, the resulting center door deflection is reduced. The resulting dynamic shear around the door (transferred to the wall) is reduced from what would be computed for a nondeflecting plate using approximate dynamic plate theory (Figure 10). The alternatives are to use finite element analysis procedures or to modify dynamic plate theory. Finite element analysis is certainly the better approach; however, it is basically an analysis technique and is more difficult and expensive to use than the simpler approximate procedure. It is suggested that the shear calculated from approximate plate theory be adjusted by a constant for use as a door reaction required for input to wall design (Ferritto 1977).

24. The maximum reaction (REA) occurs at the moment the slab first reaches yield. At this point the combination of load and resistance is maximum. Table 1 gives maximum dynamic reaction for a simply supported plate. For the case of one side free and three sides simply-supported, the b-dimension doubled may be used. The values of pressure P and resistance

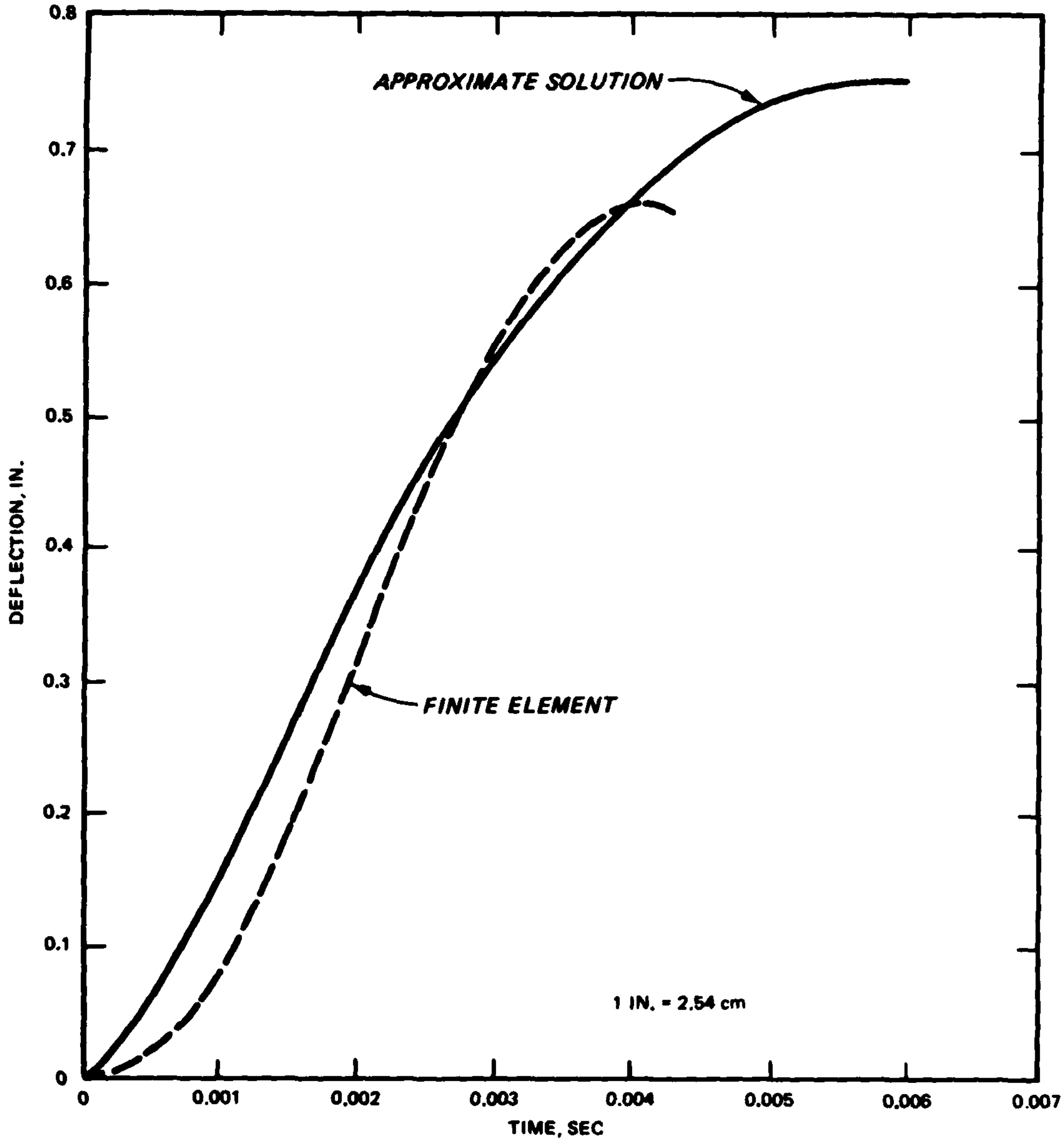


Figure 5. Displacement history of 4- by 4-ft (1.2- by 1.2-m) plate

R should correspond to time of yielding. The reaction values should be adjusted for support deflection. The value of 1.0 is suggested for non-deflecting supports and 0.5 for full deflecting supports as approximate factors. Once design has been finalized it is suggested that results be analyzed using a finite element analysis.

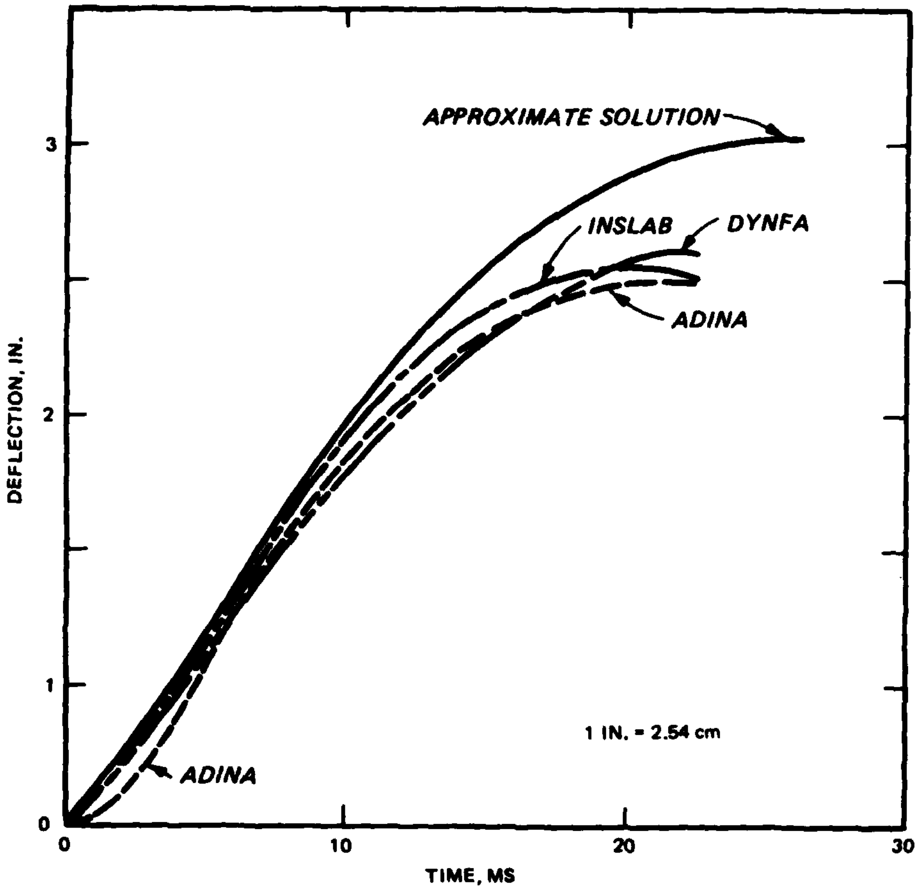


Figure 6. Deflection of center, 10-ft (3-m) beam

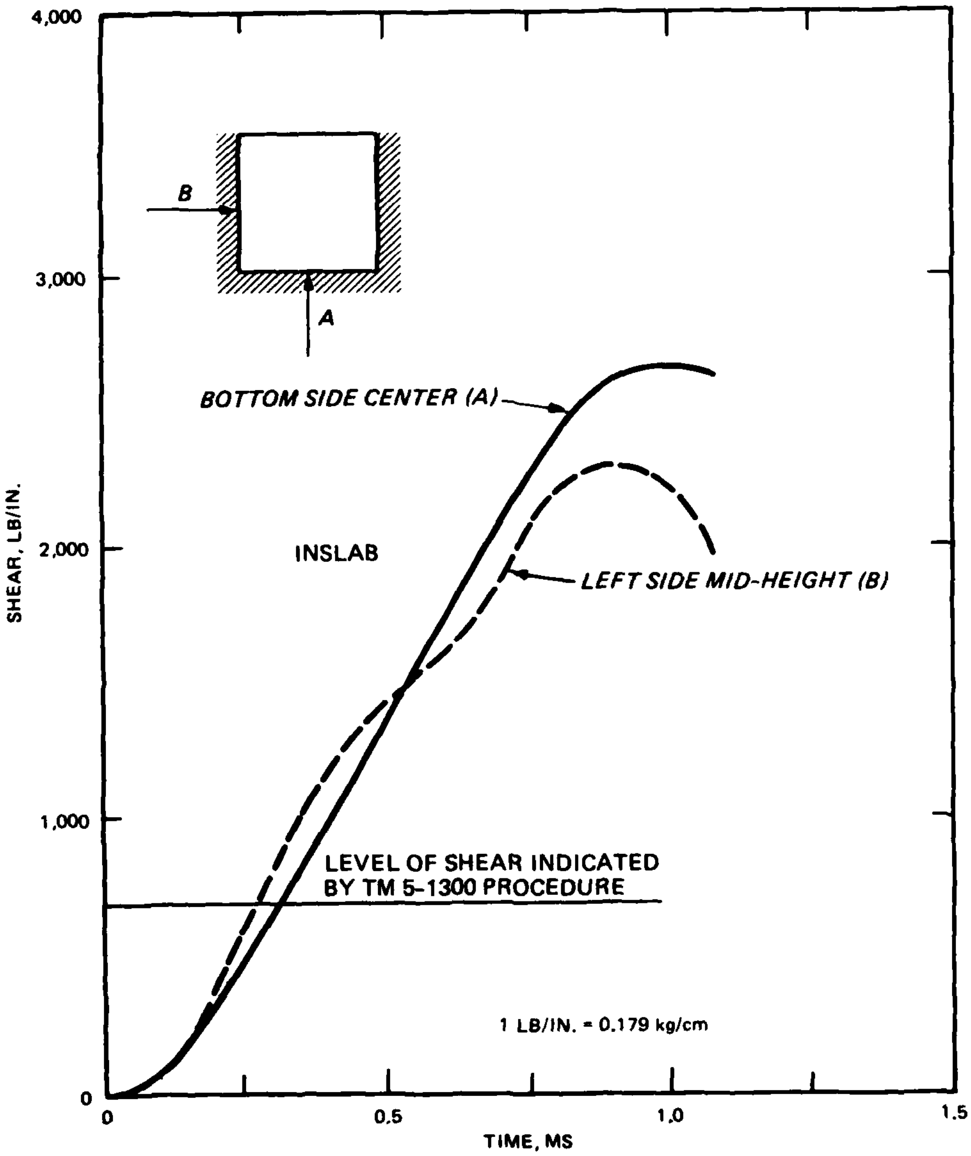


Figure 7. Shear in plate

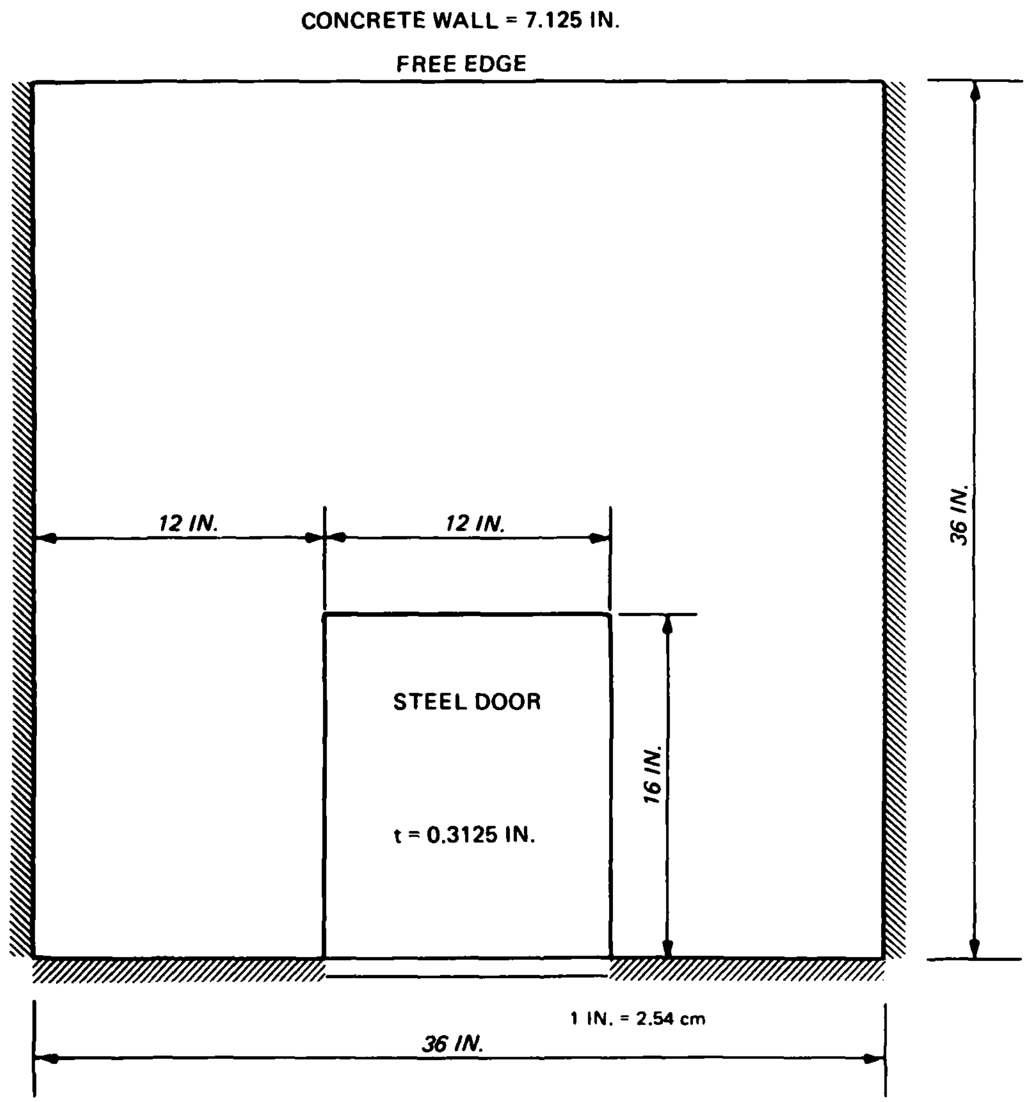


Figure 8. Geometry slab with door

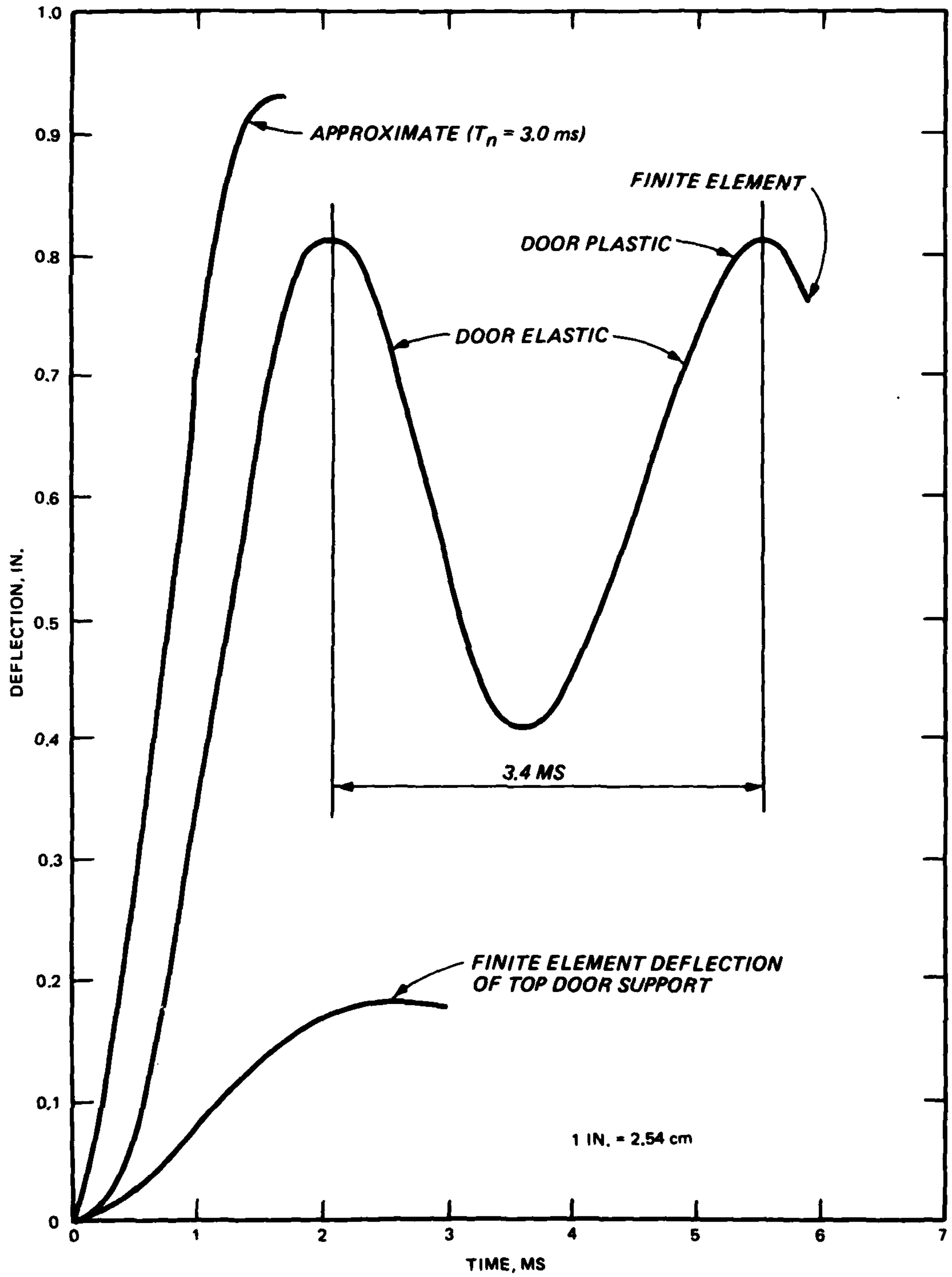


Figure 9. Deflection of door center

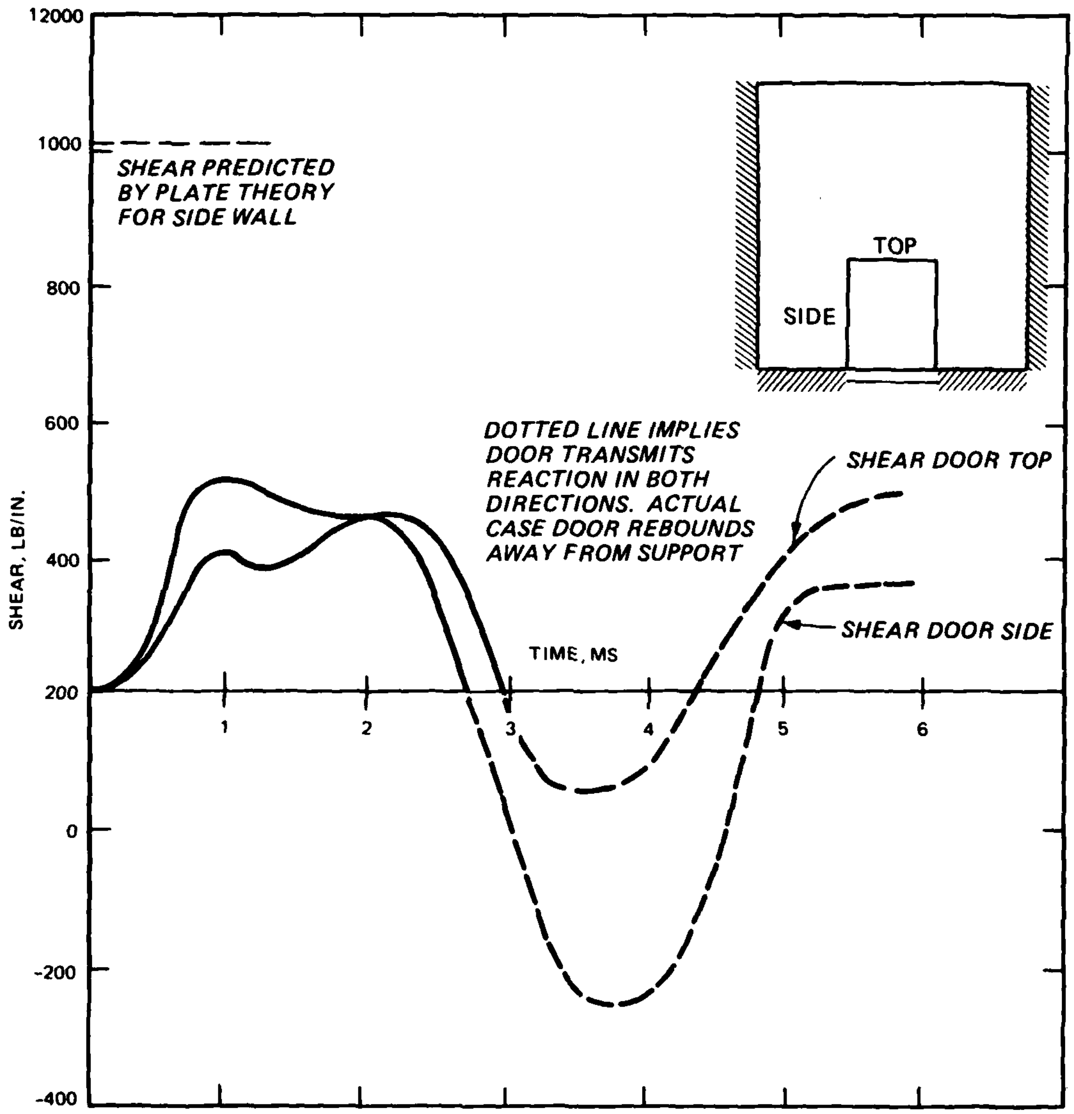
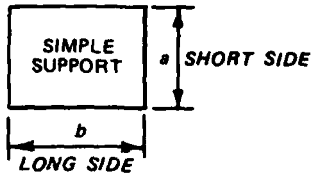


Figure 10. Door reaction

Table 1

Four Sides, Uniform Load*



Strain Range	a/b	Dynamic Reactions** V_A/b	V_B/a
Elastic	1.0	0.07P + 0.18R	0.07P + 0.18R
	0.9	0.06P + 0.16R	0.08P + 0.20R
	0.8	0.06P + 0.14R	0.08P + 0.22R
	0.7	0.05P + 0.13R	0.08P + 0.24R
	0.6	0.04P + 0.11R	0.09P + 0.26R
	0.5	0.04P + 0.09R	0.09P + 0.28R
Plastic	1.0	$0.09P + 0.16R_m$	$0.09P + 0.16R_m$
	0.9	$0.08P + 0.15R_m$	$0.09P + 0.18R_m$
	0.8	$0.07P + 0.13R_m$	$0.10P + 0.20R_m$
	0.7	$0.06P + 0.12R_m$	$0.10P + 0.22R_m$
	0.6	$0.05P + 0.10R_m$	$0.10P + 0.25R_m$
	0.5	$0.04P + 0.08R_m$	$0.11P + 0.27R_m$

* Based on information from Norris (1959).

** P = pressure at time of yield, psi
R = elastic resistance, psi
R_m = plastic resistance, psi

PART V: THE COMPUTER PROGRAM

25. The CSDOOR program is composed of four areas:

a. Blast load determination.

b. Structural analysis parameters.

c. Dynamic response.

d. Optimization.

Subroutines

Blast load determination

26. The blast-load determination is accomplished by subroutines BLA, PIC, SGRID, HBA, RATIO, GRID, GAS INTERP, EQUIV, HEDATA, ARDC, SHOCK, and TNT. The subroutines read the explosive weight and type and cell geometry. The equivalent spherical weight of TNT and the equivalent pressure loading is computed based on the geometry of the wall and charge location. Both the shock pressure and its duration and the gas pressure and its duration are calculated. Using the duration and pressure data for both shock and gas, the program computes an equivalent triangular pressure loading for each part and adds both to produce the resultant shown in Figure 11. The total impulse is then determined.

Structural analysis

27. The structural analysis is accomplished by subroutines SSTIFF, DOOR1, DOOR2, DOOR3, DOOR4, and DOOR5. These routines compute the stiffness, resistance, and equivalent mass of the plate using input material properties as in TM 5-1300. Both flexure and shear are considered. Openings in plates are allowed.

Dynamic response

28. The dynamic response calculation is accomplished in subroutine RESP. The program determines the response of the plate modeled as an equivalent dynamic single-degree-of-freedom system with bilinear stiffness and the pressure loading shown in Figure 11. The solution technique is based on a Newmark iteration method.

Optimization

29. The optimization of an initial design is accomplished in subroutines OPT, MINIMZ, PMINZ, DMINZ, GETE, SUMRY, TLEFT, and GCOMP. The

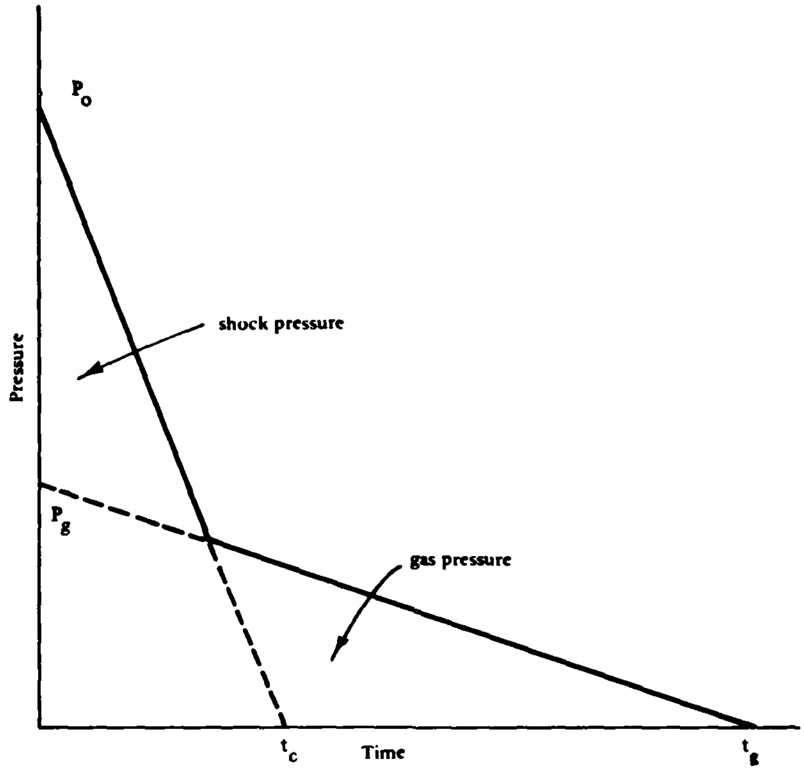


Figure 11. Equivalent pressure loading

methodology used is that of a penalty function with individual minimization sequences being accomplished by the Powell method.

Program Input

Data input guide

30. The following sections describe the data input phase of CSDOOR and the various options available. A data input guide was prepared to aid the user in data preparation. This guide, with appropriate entries, is presented in Appendix A with each example problem. Also, a blank copy of the guide is presented at the back of this report. Illustrative results are presented for the following example problems:

- a. Analyze steel door.
- b. Analyze steel plate.
- c. Analyze steel wall.

Data groups

31. Defining a problem involves specification of 7 basic data groups

composed of about 48 variables. The program can be run by making use of an existing data file having sequence numbers at the start of each line. As an alternative mode of input, an interactive phase is also provided which assists the user in defining data for a particular problem. All data are entered in free-field format with commas or blanks used to separate the successive numbers. All values can be input with or without decimal points (for instance, FLAG1 = 1 can be input either as 1. or as 1). If the user so desires, data input interactively can be saved into a permanent file with line numbers. The output from a problem can be written to the terminal or into a permanent file to be either scanned with an editor or sent to a line printer.

32. The user should be aware that data saved in a file may not coincide exactly with the values input interactively. The data are written to a file using field widths adequate for practical situations. For instance, most variables are written using two digits past the decimal point. In the event that greater accuracy is needed in the recorded data, the data file can be edited accordingly.

33. The different data groups with names of the variables for each one as used in the program are as follows:

a. Data Group 1--Heading (HDG):

HDG - Alphanumeric heading for problem identification; 68 characters maximum

b. Data Group 2--Program Control (FLAG1, FLAG2, FLAG3, FLAG4, FLAG5, PC, COST):

FLAG1* - Set = 1 for optimization; otherwise = 0

FLAG2 - Set = 0 to calculate gas pressure; set = 1 to input gas pressure

FLAG3 - Set = 0 for plate thickness (TS); set = 1 for section modulus (Z) and moment of inertia (I)

FLAG4 - Set = 1 for impulse grid; otherwise = 0

FLAG5 - Set = 1 for door/window reaction present; otherwise = 0

PC - Set = 0 for standard printout
= 1 for print response time-history

---

* Optimization cannot be used if a composite door is used (FLAG3 = 1) or if a door is present (FLAG5 = 1).

COST - Cost of steel per dollars per lb* (default = 0.60)

c. Data Group 3--Load Parameters (WLB, ANUM, RLOD, CASE, APAMB, TAMB, ALTKFT):

WLB - Weight of actual explosive including safety factor, lb

ANUM - Explosive number used to compute explosive equivalence (see Table 2 for list of explosives)

RLOD - Explosive length to diameter ratio (default = 1)

CASE - Projectile case weight to explosive weight ratio (use 0 for conservative analysis)

APAMB - Ambient air pressure, psia (default = 14.69)

TAMB - Ambient temperature, °C (default = 20°C)

ALTKFT - Altitude, 10^3 ft (when APAMB and TAMB not specified)

d. Data Group 4--Geometry:

(1) When gas pressure is calculated (FLAG2 = 0) input (RA, H, EL, HLIT, ELLIT, AV, AC, ICODE(i), where i = 1, 2, 3, and 4):

RA - Distance from charge to wall, ft

H - Wall height, ft

EL - Wall length, ft

HLIT - Height of charge, ft

ELLIT - Distance of charge to left boundary, ft

AV - Cell volume for gas pressure, ft^3

AC** - Cell vent area for gas pressure, ft^2

ICODE(1) - Set = 1 for floor reflection; otherwise set = 0

ICODE(2) - Set = 1 for roof reflection; otherwise set = 0

ICODE(3) - Set = 1 for left wall reflection; otherwise set = 0

ICODE(4) - Set = 1 for right wall reflection; otherwise set = 0

---

* A table of factors for converting U. S. customary (NON-SI) units of measurement to metric (SI) units is presented on page 5.

** CSDOOR will not solve for gas pressure if vent area = 0.

Table 2

List of Explosives

Explosive Number	Explosive Name and Composition
1	TNT
2	TNETB
3	EXPLOSIVE D
4	PENTOLITE (PETN/TNT 50/50)
5	PICRATOL (EXPLOSIVE D/TNT 52/48)
6	CYCLOTOL (RDX/TNT 70/30)
7	COMP B (RDX/TNT/WAX 59.4/39.6/1.0)
8	RDX/WAX (98/2)
9	COMP A-3 (RDX/WAX 91/9)
10	TNETB/AL (90/10)
11	TNETB/AL (78/22)
12	TNETB/AL (72/28)
13	TNETB/AL (65/34)
14	TRITONAL (TNT/AL80/70)
15	RDX/AL/WAX (88/10/2)
16	RDX/AL/WAX (89/20/2)
17	RDX/AL/WAX (74/21/5)
18	RDX/AL/WAX (74/22/4)
19	RDX/AL/WAX (62/33/5)
20	TORPEX II (RDX/TNT/AL 42/40/18)
21	H6 (RDX/TNT/AL/WAX 45/29/21/5)
22	HBX-1 (RDX/TNT/AL/WAX 40/38/16/5)
23	HBX-3 (RDX/TNT/AL/WAX 31/29/35/5)
24	TNETB/RDX/AL (39/26/35)
25	ALUMINUM
26	WAX
27	RDX
28	PETN
29	TETRYL

(2) <u>When gas pressure is input (FLAG2 = 1) input (TOTIM, H, EL, FPRES, TO, PG, TG, ICODE(i), where i = 1, 2, 3, and 4):</u>

TOTIM - Total impulse, psi-msec

H - Wall height, ft

EL - Wall length, ft

FPRES - Peak pressure, psi

TO - Duration of peak pressure, msec

PG - Gas pressure, psi

TG - Gas pressure duration, msec

ICODE(1) - Set = 1 for floor reflection; otherwise set = 0

ICODE(2) - Set = 1 for roof reflection; otherwise set = 0

ICODE(3) - Set = 1 for left wall reflection; otherwise set = 0

ICODE(4) - Set = 1 for right wall reflection; otherwise set = 0

e. <u>Data Group 5--Strength Parameters (FDY, TS, SN, DH, DEL, U, E):</u>

FDY - Steel dynamic design strength, psi

TS* - Door thickness, in.

SN - Support code (see Figure 12):

= 1, bottom fixed
= 2, bottom and 1 side fixed
= 3, bottom and 2 sides fixed
= 4, 4 sides fixed
= 5, beam simple supports top and bottom
= 6, beam fixed top and bottom
= 7, beam, simple support top, fixed bottom
= 13, three sides simple supports, bottom free
= 14, four sides simple support

DH* - Door height, ft

DEL* - Door width, ft

U - Allowable ductility limit for optimization

E - Modulus of elasticity, psi

f. <u>Data Group 6--Door Properties (ZHOR, ZVERT, IAVG, WDR):</u>

ZHOR - Plastic horizontal section modulus/in., $in.^3/in.$

---

* Door and wall are synonymous when door height and width equal wall height and width.

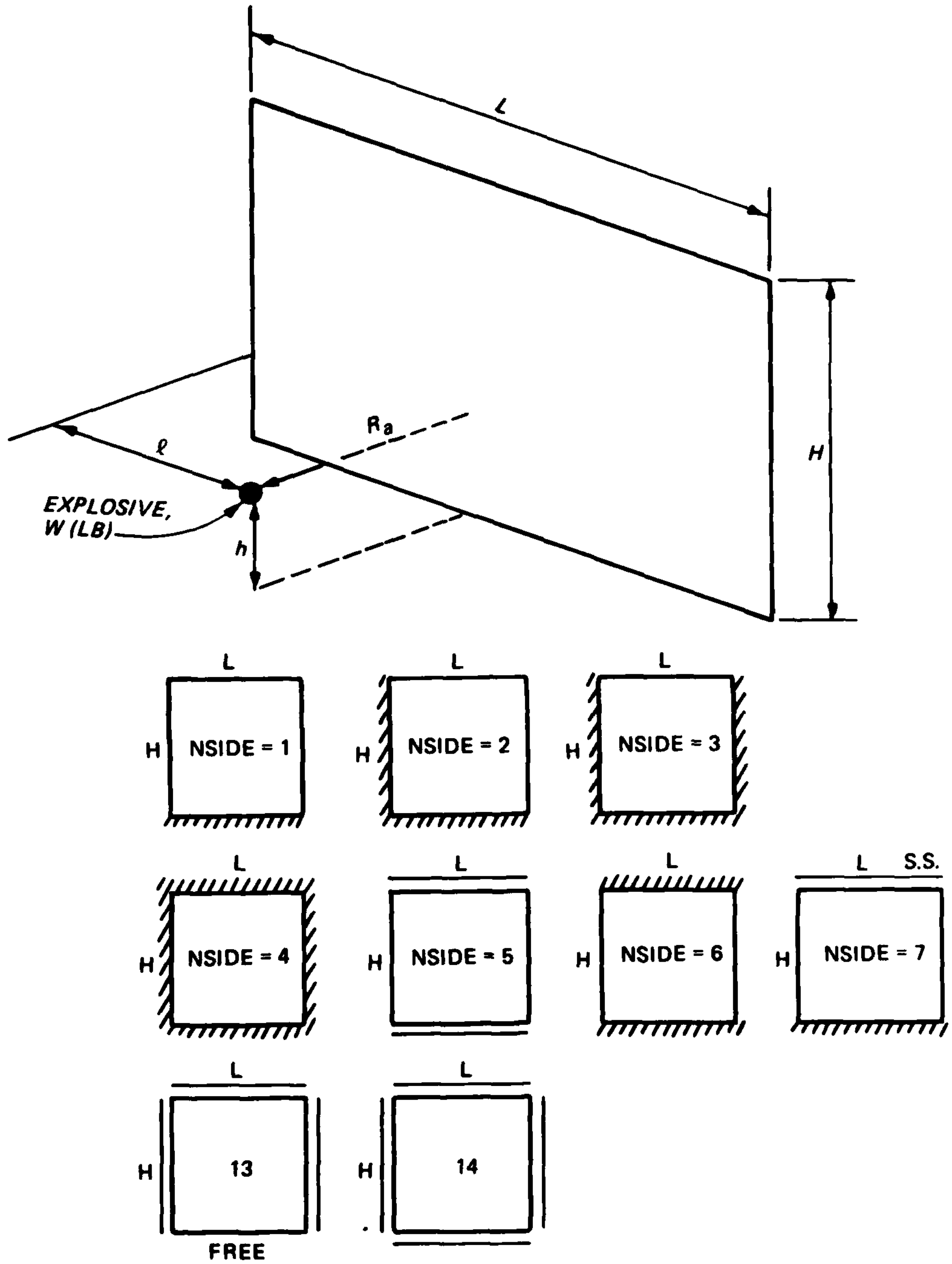


Figure 12. Plate geometry

ZVERT	- Plastic vertical section modulus/in., in.^{3}/in.
IAVG	- Average moment of inertia/in., in.^{4}/in.
WDR	- Total door weight, lb

g. <u>Data Group 7--Opening (Panel) Parameters* (see Figure 13) when FLAG5 = 1 input (H2, WT, B, REA, RD1, H1):</u>

H2	- Opening height, ft
WT	- Opening width, ft
B	- Distance from left side to opening, ft
REA	- Opening reaction, lb/in. (3 sides supported)
RD1	- Resistance for calculating opening reaction, lb (3 sides supported)
H1	- Distance to floor, ft (for window only)

34. The explosive number (Data Group 3) refers to the list of explosives in Table 2. This number is used to compute explosive equivalence. The length/diameter ratio for an explosive sphere is 0.0, which gives a shape factor of 1.0. For an uncased explosive the case explosive weight ratio is 0.0. For sea level calculations, the ambient air pressure P_{amb}, temperature T_{amb}, and altitude can be left blank and will default to 14.69 psi and 20°C. If FLAG2 in Data Group 2 is set to 1, the impulse, duration, and pressure will be read on Date Group 4. If FLAG2 is set to zero, the charge to wall distance, charge height, and distance from the left side will be read. If SN is zero, the program will sum the number of reflecting sidewall surfaces specified in Data Group 4. The separate use of SN is helpful when a frangible wall is present, which creates a shock reflection but does not provide any support.

35. The SN (see Figure 12) conditions 1 through 4 are intended to be used to represent steel cell walls and roofs; SN conditions 5 through 7 are steel plates spanning in one direction. The SN conditions 13 and 14 are specifically intended to represent typical steel plate doors and pass-through windows.

---

* When an opening (panel) is present, the program analyzes the wall as a door. The panel reaction must be provided either as a resistance (lb/in.) along the edges of the panel or as a resistance (psi) over the entire panel. This case seldom occurs in practice.

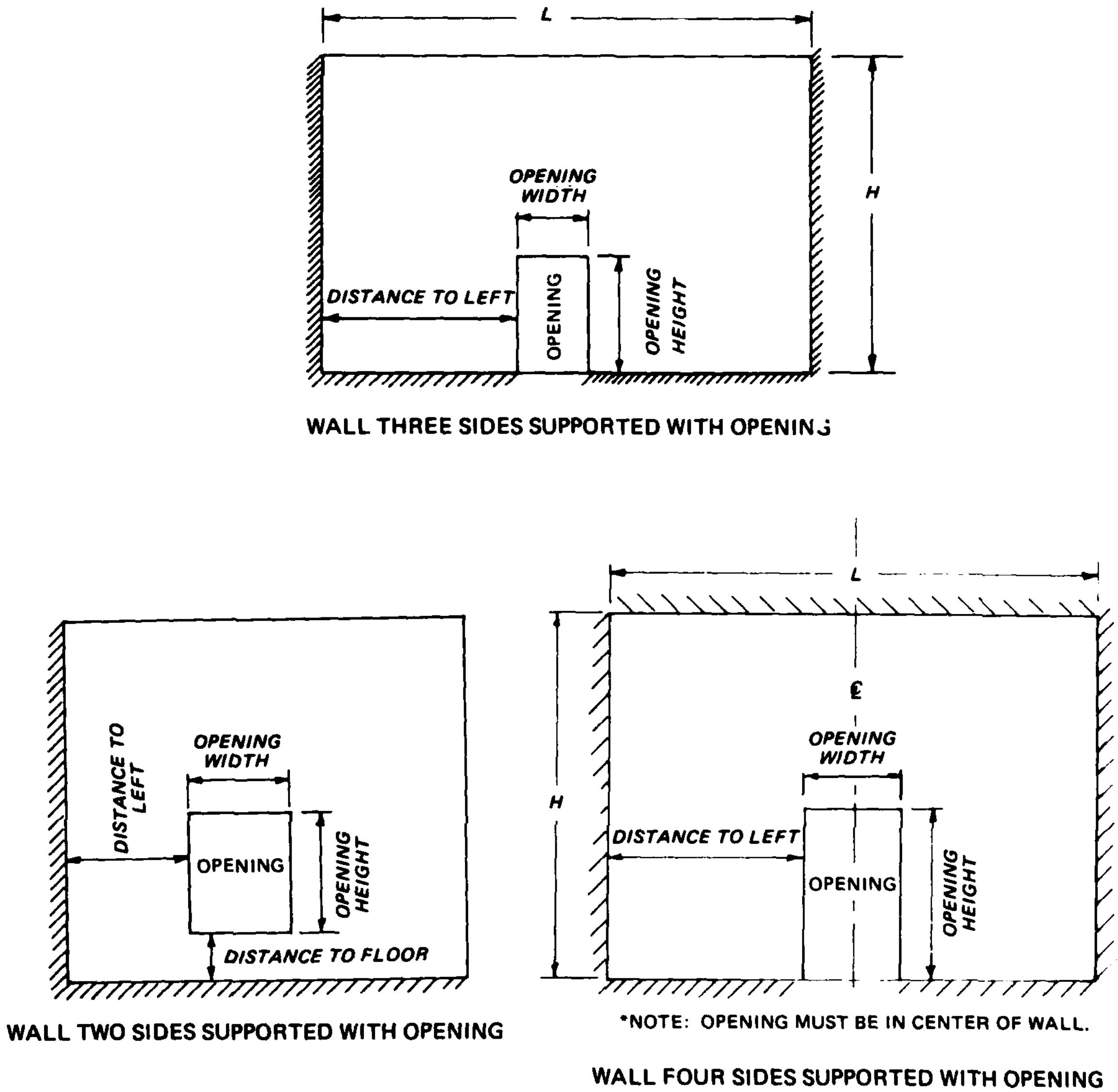


Figure 13. Wall geometry with opening

Example Problems

36. Three example problems are presented in Appendix A. In examples 1 and 2, data were entered from a data file. In example 3, data were entered interactively.

REFERENCES

Gill, J. O., et al. 1973. "Preliminary Report on the Modernization of the Naval Ordnance Production Base and Application of Hazard Risk Analysis Technique," paper presented at the Fifteenth Explosive Safety Seminar, Department of Defense Explosive Safety Board, San Francisco, Calif.

Mendolia, Arthur. 1973. "A New Approach to Explosives Safety," paper presented at the Fifteenth Explosive Safety Seminar, Department of Defense Explosive Safety Board, San Francisco, Calif.

Departments of the Army, Navy, and Air Force. 1969. "Structures to Resist the Effects of Accidental Explosions," TM 5-1300, NAVFAC P-397, AFM 88-22, Washington, D.C.

Ferritto, John M. 1977. "Optimum Dynamic Design of Nonlinear Reinforced Concrete Slabs Under Blast Loading," TN-1494, Civil Engineering Laboratory, Port Hueneme, Calif.

Fox, R. L. 1971. Optimization Methods for Engineering Design, Addison Wesley, Reading, Mass.

Pope, G. and Schmit, L. H., eds. 1971. "Structural Design Applications of Mathematical Programming Techniques," AGARD No. 149, Advisory Group for Aerospace Research and Development, North Atlantic Treaty Organization, Neuilly-sur Seine.

Norris, Charles H., et al. 1959. Structural Design for Dynamic Loads, McGraw-Hill Book Company, Inc., New York.

APPENDIX A: EXAMPLE PROBLEM 1, ANALYZE STEEL DOOR

Given

Geometry as shown

Charge Wt. = 10.0 lb Comp B (uncased)

Floor, roof, left wall and right wall deflection

FDY = 48000 psi

Three sides simply supported bottom free

Allowable ductility $\mu = 3$

Required

Analyze steel door

Assume

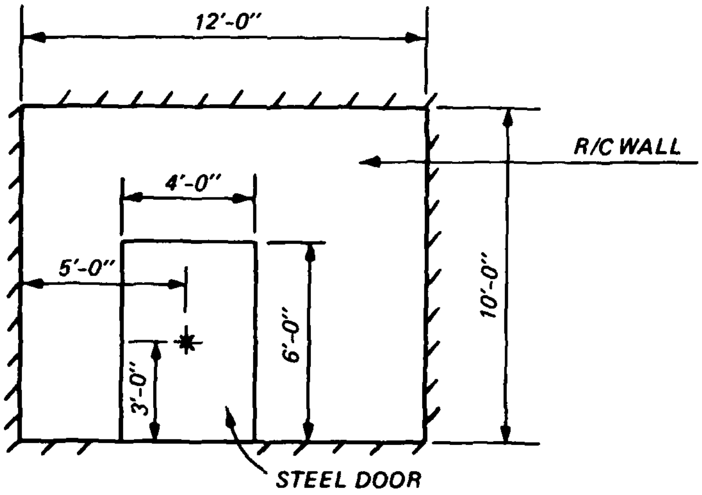
Plastic section modulus horiz. = 1.77 in.^{3}/in.

Plastic section modulus vert. = 1.51 in.^{3}/in.

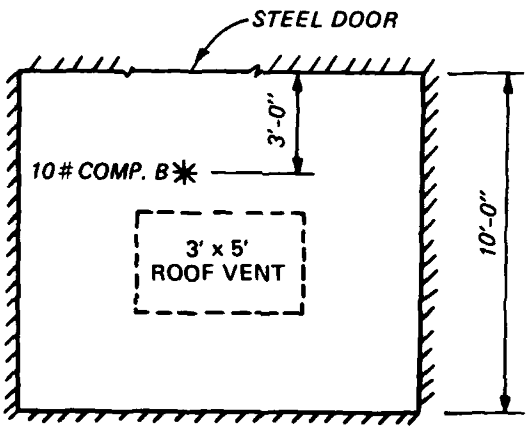
Average moment of inertia = 3.495 in.^{4}/in.

Door weight = 920 lbs

Example Problem 1



ELEVATION



PLAN

CSDOOR Data Format

FILENAME - **DOOREX1**

	HEADING (JOB DESCRIPTION)										
Line 1	**EXAMPLE PROBLEM ONE**										
	OPTIONS										
	FLAG1	FLAG2	FLAG3	FLAG4	FLAG5	PC		COST $/lb (Default = 0.60)			
	0 = Analyze 1 = Optimize	0 = Calc. Blast Load 1 = Input p-t History	0 = Input Door TS 1 = Input Door Z	0 = Omit Grid 1 = Calculate Grid	0 = No Opening in Door 1 = Opening in Door	0 = Standard Printout 1 = Print Response-Time History					
Line 2	**0**	**0**	**1**	**0**	**0**	**0**		**0**			
	WLB lb	ANUM (Default = 1.0)	RLOD (Default = 1.0)	CASE	APAMB, psia (Default = 14.69)	TAMB, °C (Default = 20.0)	ALTKFT 10^3 ft				
If FLAG2 = 0, Line 3	**10**	**7**	**1**	**0**	**0**	**0**	**0**				
	RA ft	H ft	EL ft	HLIT ft	ELLIT ft	AV ft^3	AC ft^2	ICODE			
								F	R	L	R
If FLAG2 = 0, Line 4a	**3**	**10**	**12**	**3**	**5**	**1200**	**15**	**1**	**1**	**1**	**1**
	TOTIM psi-msec	H ft	EL ft	PRES psi	TO msec	PG psi	TG msec	ICODE			
								F	R	L	R
If FLAG2 = 1, Line 4b											
	FDY psi	TS in.	SN	DH ft	DEL, ft If ≠ EL	U	E, psi (Default = 29,000,000)				
Line 5	**48000**	**0**	**13**	**6**	**4**	**3**	**0**				
	ZHOR $in.^3/in.$	ZVERT $in.^3/in.$	IAVG $in.^4/in.$	WDR lb							
If FLAG3 = 1, Line 6	**1.77**	**1.51**	**3.496**	**920**							
	H2 ft	WT ft	B ft	REA lb/in.	RD1 psi	H1 ft					
If FLAG5 = 1, Line 7											

NOTE: For time-sharing applications, all entries (including 0) must be made for each required line of data.
Optimization cannot be used if FLAG3 = 1 or FLAG5 = 1.
Door and wall are synonymous when DH = H and DEL = EL.
FLAG5 = 1 can only be used when SN = 2, 3, or 4.

```
1000     E X A M P L E   P R O B L E M   O N E
1010 0 0 1 0 0 0 0
1020 10 7 1 0 0 0 0
1030 3 10 12 3 5 1200 15 1 1 1 1
1040 48000 0 13 6 4 3 0
1050 1.77 1.51 3.495 920
C>X0057
                ********************CAUTION********************

                THIS PROGRAM SHOULD BE USED ONLY BY ENGINEERS
                WHO ARE EXPERIENCED IN BLAST DESIGN AND ARE
                THOROUGHLY FAMILIAR WITH METHODS OF ANALYSIS
                DESCRIBED IN TM 5-1300 'STRUCTURES TO RESIST
                THE EFFECTS OF ACCIDENTAL EXPLOSIONS.'  CONNECTIONS
                AND DETAILS MUST BE CAREFULLY DESIGNED TO ACHIEVE
                THE DEGREE OF FIXITY THAT IS ASSUMED IN THE PROGRAM

                ********************CAUTION********************

 INPUT NAME OF DATA FILE IN 7 CHARACTERS OR LESS
 HIT A CARRIAGE RETURN IF DATA TO COME FROM TERMINAL.
I>DOOREX1

 INPUT NAME OF FILE FOR OUTPUT TO BE WRITTEN TO.
 HIT A CARRIAGE RETURN IF OUTPUT TO TERMINAL
I>



    E X A M P L E   P R O B L E M   O N E
 COMP B (RDX/TNT/WAX,59.4/39.6/1.0)
 EXPLOSIVE PROPERTIES......CHARGE WEIGHT(LB) =  10.00
 NUMBER EQWT   EFORM EXPLOSIVE COMPOSITION BY WEIGHT
             KCAL/G     C     H     N     O    AL
   7  1.100  .004330  .252  .026  .298  .424 0.000


 PAMB(PSIA)=  14.69       TAMB(C)=  20.00

                      SHOCK WAVE CALCULATION
 INPUT PARAMETERS                          CHARGE WEIGHT ADJUSTMENTS

 CHARGE WEIGHT(LB)      =    10.00        ADJUSTED WT(LB TNT)  =   11.00
 EXPLOSIVE NUMBER       =      7          HE ENERGY FACTOR     =   1.100
 L/D RATIO              =    1.000        CHARGE SHAPE FACTOR  =   1.000
 CASE/CHARGE WT RATIO   =  0.             CASE WEIGHT FACTOR   =   1.000
```

```
CHAMBER PRESSURE(PSIA)=   14.69        PRESSURE SCALE FACTOR=   1.000
CHAMBER TEMP(C)       =   20.00        DISTANCE SCALE FACTOR=   .4496
ALTITUDE (KFT)        =  0.            TIME SCALE FACTOR    =   .4535
                                       NORMAL REFL* FACTOR  =   7.526
DESIRED DISTANCE (FT) =   3.000
                 (CM) =   91.44
```

TIME AFTER EXPLOSION (MSEC)	TIME AFTER SHOCK ARR (MSEC)	INCIDENT OVERPRESS (PSI)	NORM REFL OVERPRESS (PSI)
.2615	0.	497.2	3742.
.3698	.1083	156.8	1180.
.4240	.1625	98.81	743.6
.4782	.2167	64.16	482.9
.5324	.2708	41.97	315.9
.5865	.3250	27.05	203.6
.6407	.3792	16.66	125.4
.6949	.4334	9.259	69.68
.7490	.4875	3.905	29.39
.8032	.5417	0.	0.

```
IMPULSE (PSI.MSEC)--
    INCIDENT =   53.86
    REFLECTED=   405.3
.....CAUTION--CNTACT SURFACE HAS ARRIVED.
        DATA ARE CRUDE BEYOND T(MSEC) AFTER SHOCK ARRIVAL=  7.5617E-02
```

DISTANCE OF CHARGE FROM BLAST WALL	FT.	3.00
CHARGE WEIGHT	LBS.	11.00
BLAST WALL HEIGHT	FT.	10.00
BLAST WALL LENGTH	FT.	12.00
HEIGHT OF CHARGE ABOVE GROUND	FT.	3.00
MIN. DIST. BETWEEN CHARGE + ADJ. WALL	FT.	5.00
REFLECTION CODE		1 1 1 1

```
         TOTAL  IMPULSE          440.28 PSI-MS
VENT AREA     15.00  FT2   CELL VOLUME     1200.00  FT3
```

GAS PRESSURES CALCULATION

PEAK GAS PRESSURE	68.85	PSI
GAS DURATION	91.84	MSEC
GAS IMPULSE	3161.46	PSI-MSEC
TOTAL IMPULSE	3299.79	PSI-MSEC

DURATION OF LOAD	5.72156	MSEC

FICTITIOUS PEAK PRESSURE	153.90	PSI
EFFECTIVE IMPULSE	3299.79	PSI-MSEC

FS DYNAMIC	48000.00	PSI
PLATE THICKNESS	0.00	IN
SUPPORT CODE	13.00	
DOOR HEIGHT	6.00	FT
DOOR LENGTH	4.00	FT
PLASTICITY (MU)	3.00	
HORIZONTAL Z	1.77	IN3/IN
VERTICAL Z	1.51	IN3/IN
I AVERAGE	3.50	IN4/IN
DOOR WEIGHT	920.00	LBS

HEIGHT	72.00	IN	LENGTH	48.00	IN

POSITIVE VERTICAL MOMENT	72480.00	IN-LBS/IN WIDTH
NEGATIVE VERTICAL MOMENT	72480.00	IN-LBS/IN WIDTH
POSITIVE HORIZONTAL MOMENT	84960.00	IN-LBS/IN WIDTH
NEGATIVE HORIZONTAL MOMENT	84960.00	IN-LBS/IN WIDTH

THREE SIDES SIMPLY SUPPORTED

X	24.0000	IN
Y	32.7453	IN
RU	417.4331	PSI
W1	423.3625	PSI
W2	405.5744	PSI

XE	.2909	IN
K	1435.13	LB/IN/IN2
MASS	469.15	LB-MSEC2/IN/IN2

ALLOWABLE MAX DEFLECTION	.8726	IN

MASS	469.150	LB-MSEC2/IN/IN2
LOAD	153.902	PSI
DURATION	5.722	MSEC
RESISTANCE	417.433	PSI

```
STIFFNESS       1435.131  LB/IN/IN2
GAS PRESSURE      68.85   PSI
DURATION          91.84   MSEC


MEMBRANE YIELD DEFLECTION      1.518582  IN

ELASTIC DEFLECTION LIMIT        .290868  IN

MAXIMUM DEFLECTION              .181843  IN

NATURAL PERIOD                 3.592439  MSEC

TIME TO MAXIMUM DEFLECTION     1.678216  MSEC

DURATION/NATURAL PERIOD       25.565389

LOAD/RESISTANCE                 .368687
1.200 CP SECONDS EXECUTION TIME.
C>
```

APPENDIX B: EXAMPLE PROBLEM 2, ANALYZE STEEL PLATE

<u>Given</u>

Geometry as shown

Charge wt = 10 lbs T.N.T.

Explosive length to diameter ratio 2.5

Case to explosive ratio 1.2

Floor, left wall and right wall reflection

Four sides simply supported

FDY = 48000 psi

Allowable ductility $\mu = 5$

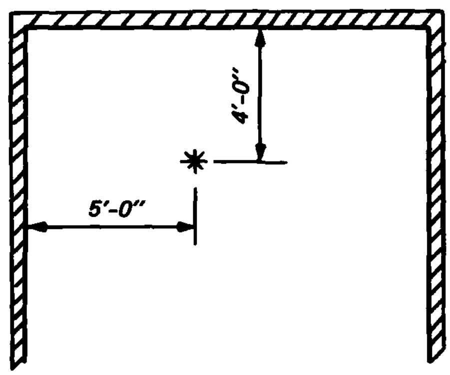
<u>Required</u>

Analyze steel plate

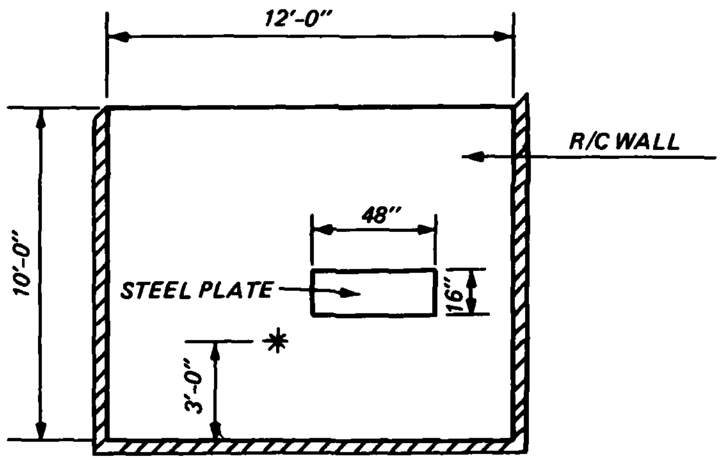
<u>Assume</u>

Plate thickness 0.75 in.

Example Problem 2



PLAN



ELEVATION

CSDOOR Data Format

FILENAME - **DOOREX2**

	HEADING (JOB DESCRIPTION)										
Line 1	**EXAMPLE PROBLEM TWO**										
	OPTIONS										
	FLAG1	FLAG2	FLAG3	FLAG4	FLAG5	PC		COST $/lb (Default = 0.60)			
	0 = Analyze 1 = Optimize	0 = Calc. Blast Load 1 = Input p-t History	0 = Input Door TS 1 = Input Door Z	0 = Omit Grid 1 = Calculate Grid	0 = No Opening in Door 1 = Opening in Door	0 = Standard Printout 1 = Print Response-Time History					
Line 2	**0**	**0**	**0**	**0**	**0**	**0**		**0**			
	WLB lb	ANUM (Default = 1.0)	RLOD (Default = 1.0)	CASE	APAMB, psia (Default = 14.69)	TAMB, °C (Default = 20.0)	ALTKFT 10^3 ft				
If FLAG2 = 0, Line 3	**10**	**1**	**2.5**	**1.2**	**14.69**	**20**	**0**				
	RA ft	H ft	EL ft	HLIT ft	ELLIT ft	AV ft^3	AC ft^2	ICODE			
								F	R	L	R
If FLAG2 = 0, Line 4a	**4**	**10**	**12**	**3**	**5**	**0**	**0**	**1**	**0**	**1**	**1**
	TOTIM psi-msec	H ft	EL ft	PRES psi	TO msec	PG psi	TG msec	ICODE			
								F	R	L	R
If FLAG2 = 1, Line 4b											
	FDY psi	TS in.	SN	DH ft	DEL, ft If ≠ EL	U	E, psi (Default = 29,000,000)				
Line 5	**48000**	**0.75**	**14**	**1.33**	**4**	**5**	**0**				
	ZHOR $in.^3/in.$	ZVERT $in.^3/in.$	IAVG $in.^4/in.$	WDR lb							
If FLAG3 = 1, Line 6											
	H2 ft	WT ft	B ft	REA lb/in.	RD1 psi	HI ft					
If FLAG5 = 1, Line 7											

NOTE: For time-sharing applications, all entries (including 0) must be made for each required line of data.
Optimization cannot be used if FLAG3 = 1 or FLAG5 = 1.
Door and wall are synonymous when DH = H and DEL = EL.
FLAG5 = 1 can only be used when SN = 2, 3, or 4.

```
1000     E X A M P L E   P R O B L E M   T W O
1010 0 0 0 0 0 0 0
1020 10 1 2.5 1.2 14.69 20 0
1030 4 10 12 3 5 0 0 1 0 1 1
1040 48000 0.75 14 1.33 4 5 0
C>X0057
               ********************CAUTION********************

               THIS PROGRAM SHOULD BE USED ONLY BY ENGINEERS
               WHO ARE EXPERIENCED IN BLAST DESIGN AND ARE
               THOROUGHLY FAMILIAR WITH METHODS OF ANALYSIS
               DESCRIBED IN TM 5-1300 'STRUCTURES TO RESIST
               THE EFFECTS OF ACCIDENTAL EXPLOSIONS.'  CONNECTIONS
               AND DETAILS MUST BE CAREFULLY DESIGNED TO ACHIEVE
               THE DEGREE OF FIXITY THAT IS ASSUMED IN THE PROGRAM

               ********************CAUTION********************

 INPUT NAME OF DATA FILE IN 7 CHARACTERS OR LESS
 HIT A CARRIAGE RETURN IF DATA TO COME FROM TERMINAL.
I>DOOREX2

 INPUT NAME OF FILE FOR OUTPUT TO BE WRITTEN TO.
 HIT A CARRIAGE RETURN IF OUTPUT TO TERMINAL
I>



    E X A M P L E   P R O B L E M   T W O
 TNT
 EXPLOSIVE PROPERTIES......CHARGE WEIGHT(LB) =  10.00
 NUMBER EQWT   EFORM EXPLOSIVE COMPOSITION BY WEIGHT
              KCAL/G      C     H     N     O    AL
    1  1.000 -.078400  .370  .022  .185  .423 0.000


 PAMB(PSIA)=  14.69       TAMB(C)=  20.00
 .....CHARGE SHARE CORRECTION IS CRUDE.  PSI EXCEEDS  RANGE OF EXPERIMENTAL DATA.
 .....CASE WEIGHT CORRECTION IS CRUDE. PSI EXCEEDS  RANGE OF EXPERIMENTAL DATA.

                      SHOCK WAVE CALCULATION
 INPUT PARAMETERS                          CHARGE WEIGHT ADJUSTMENTS

 CHARGE WEIGHT(LB)      =   10.00          ADJUSTED WT(LB TNT)  =   21.41
 EXPLOSIVE NUMBER       =     1            HE ENERGY FACTOR     =   1.000
 L/D RATIO              =   2.500          CHARGE SHAPE FACTOR  =   3.012
```

CASE/CHARGE WT RATIO	=	1.200	CASE WEIGHT FACTOR	=	.7109
CHAMBER PRESSURE(PSIA)	=	14.69	PRESSURE SCALE FACTOR	=	1.000
CHAMBER TEMP(C)	=	20.00	DISTANCE SCALE FACTOR	=	.3601
ALTITUDE (KFT)	=	0.	TIME SCALE FACTOR	=	.3632
			NORMAL REFL' FACTOR	=	7.307

DESIRED DISTANCE (FT) = 4.000
(CM) = 121.9

TIME AFTER EXPLOSION (MSEC)	TIME AFTER SHOCK ARR (MSEC)	INCIDENT OVERPRESS (PSI)	NORM REFL OVERPRESS (PSI)
.3687	0.	437.8	3199.
.5129	.1442	138.1	1009.
.5850	.2163	87.00	635.7
.6571	.2884	56.49	412.8
.7292	.3605	36.96	270.0
.8013	.4326	23.82	174.0
.8733	.5047	14.67	107.2
.9454	.5767	8.152	59.57
1.018	.6488	3.438	25.12
1.090	.7209	0.	0.

IMPULSE (PSI.MSEC)--
INCIDENT = 63.11
REFLECTED= 461.1
.....CAUTION--CNTACT SURFACE HAS ARRIVED.
DATA ARE CRUDE BEYOND T(MSEC) AFTER SHOCK ARRIVAL= .1163

DISTANCE OF CHARGE FROM BLAST WALL	FT.	4.00
CHARGE WEIGHT	LBS.	21.41
BLAST WALL HEIGHT	FT.	10.00
BLAST WALL LENGTH	FT.	12.00
HEIGHT OF CHARGE ABOVE GROUND	FT.	3.00
MIN. DIST. BETWEEN CHARGE + ADJ. WALL	FT.	5.00
REFLECTION CODE		1 0 1 1

TOTAL IMPULSE 542.80 PSI-MS

DURATION OF LOAD 5.04033 MSEC

FICTITIOUS PEAK PRESSURE 215.38 PSI
EFFECTIVE IMPULSE 542.80 PSI-MSEC

FS DYNAMIC 48000.00 PSI

```
PLATE THICKNESS          .75  IN
SUPPORT CODE           14.00
DOOR HEIGHT             1.33  FT
DOOR LENGTH             4.00  FT
PLASTICITY (MU)         5.00



  HEIGHT      15.96  IN    LENGTH       48.00  IN

POSITIVE VERTICAL MOMENT       6750.00  IN-LBS/IN WIDTH
NEGATIVE VERTICAL MOMENT       6750.00  IN-LBS/IN WIDTH
POSITIVE HORIZONTAL MOMENT     6750.00  IN-LBS/IN WIDTH
NEGATIVE HORIZONTAL MOMENT     6750.00  IN-LBS/IN WIDTH

  FOUR SIDES SIMPLY SUPPORTED

 X            11.42  IN
 Y             7.98  IN
 RU          310.50  PSI

 XE           .2165  IN
 K          1434.05  LB/IN/IN2
 MASS        379.42  LB-MSEC2/IN/IN2

ALLOWABLE MAX DEFLECTION         1.0826  IN

 MASS            379.423  LB-MSEC2/IN/IN2
 LOAD            215.382  PSI
 DURATION          5.040  MSEC
 RESISTANCE      310.501  PSI
 STIFFNESS      1434.052  LB/IN/IN2
 GAS PRESSURE       0.00  PSI
 DURATION           0.00  MSEC


MEMBRANE YIELD DEFLECTION        .504928  IN

ELASTIC DEFLECTION LIMIT         .216520  IN

MAXIMUM DEFLECTION               .260201  IN

NATURAL PERIOD                  3.231908  MSEC


     TIME TO MAXIMUM DEFLECTION      1.588217  MSEC

     DURATION/NATURAL PERIOD         1.559551

     LOAD/RESISTANCE                  .693661

     CALCULATED DIF FOR FDY          1.500000

     TIME TO YIELD                 1.13059537  MSEC

     1.434 CP SECONDS EXECUTION TIME.
C>
```

APPENDIX C: EXAMPLE PROBLEM 3, ANALYZE STEEL WALL

<u>Given</u>

Geometry as shown

Pressure-time history

Bottom and two sides fixed

Allowable ductility $\mu = 3$

No reflecting surfaces

FY = 48000 psi

<u>Required</u>

Analyze steel wall

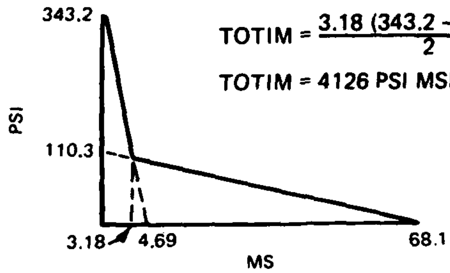
<u>Assume</u>

Wall properties as given

<u>Note</u>

Data input from terminal

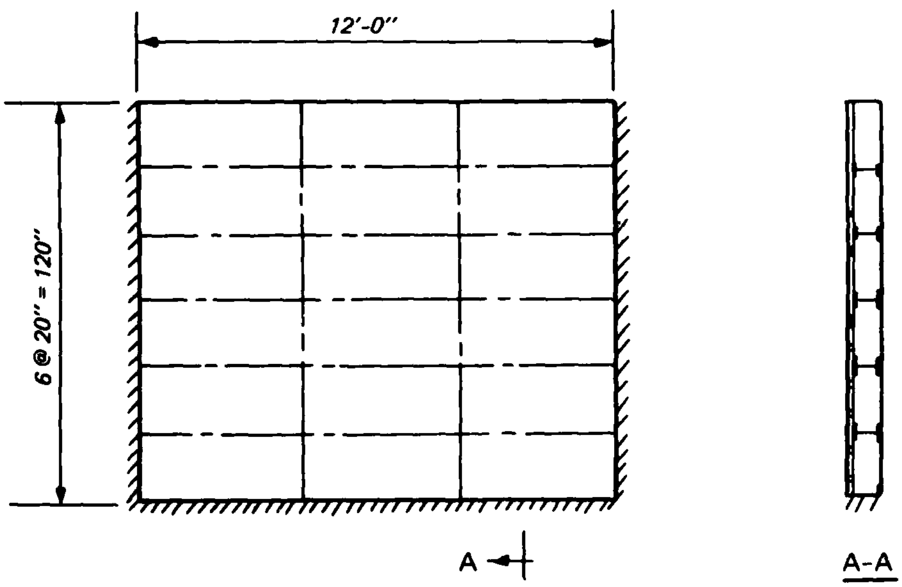
Example Problem 3



$$TOTIM = \frac{3.18\ (343.2 - 110.3)}{2} + \frac{(110.3)\ 68.1}{2}$$

TOTIM = 4126 PSI MSEC

PRESSURE-TIME HISTORY



WALL ELEVATION

WALL PROPERTIES: I_a = 9.72 IN.^{4}/IN.
Z_{HOR} = 3.67 IN.^{3}/IN.
Z_{VERT} = 1.42 IN.^{3}/IN.
WDR = 7368 LB

CSDOOR Data Format

FILENAME =

	HEADING (JOB DESCRIPTION)										
Line 1	EXAMPLE PROBLEM THREE										
	OPTIONS										
	FLAG1	FLAG2	FLAG3	FLAG4	FLAG5	PC		COST $/lb (Default = 0.60)			
	0 = Analyze 1 = Optimize	0 = Calc. Blast Load 1 = Input p-t History	0 = Input Door TS 1 = Input Door Z	0 = Omit Grid 1 = Calculate Grid	0 = No Opening in Door 1 = Opening in Door	0 = Standard Printout 1 = Print Response-Time History					
Line 2	0	1	1	0	0	0		0			
	WLB lb	ANUM (Default = 1.0)	RLOD (Default = 1.0)	CASE	APAMB, psia (Default = 14.69)	TAMB, °C (Default = 20.0)	ALTKFT 10^3 ft				
If FLAG2 = 0, Line 3											
	RA ft	H ft	EL ft	HLIT ft	ELLIT ft	AV ft^3	AC ft^2	ICODE			
								F	R	L	R
If FLAG2 = 0, Line 4a											
	TOTIM psi-msec	H ft	EL ft	FRES psi	TO msec	PG psi	TG msec	ICODE			
								F	R	L	R
If FLAG2 = 1, Line 4b	4126	10	12	343.2	4.69	110.3	68.1	0	0	0	0
	FDY psi	TS in.	SN	DH ft	DEL, ft if ≠ EL	U	E, psi (Default = 29,000,000)				
Line 5	48000	0	3	0	0	3	0				
	ZHOR $in.^3/in.$	ZVERT $in.^3/in.$	IAVG $in.^4/in.$	WDR lb							
If FLAG3 = 1, Line 6	3.67	1.42	9.72	7368							
	H2 ft	WT ft	B ft	REA lb/in.	RD1 psi	H1 ft					
If FLAG5 = 1, Line 7											

NOTE: For time-sharing applications, all entries (including 0) must be made for each required line of data.
Optimization cannot be used if FLAG3 = 1 or FLAG5 = 1.
Door and wall are synonymous when DH = H and DEL = EL.
FLAG5 = 1 can only be used when SN = 2, 3, or 4.

```
********************CAUTION********************

THIS PROGRAM SHOULD BE USED ONLY BY ENGINEERS
WHO ARE EXPERIENCED IN BLAST DESIGN AND ARE
THOROUGHLY FAMILIAR WITH METHODS OF ANALYSIS
DESCRIBED IN TM 5-1300 'STRUCTURES TO RESIST
THE EFFECTS OF ACCIDENTAL EXPLOSIONS.'  CONNECTIONS
AND DETAILS MUST BE CAREFULLY DESIGNED TO ACHIEVE
THE DEGREE OF FIXITY THAT IS ASSUMED IN THE PROGRAM

********************CAUTION********************

 INPUT NAME OF DATA FILE IN 7 CHARACTERS OR LESS
 HIT A CARRIAGE RETURN IF DATA TO COME FROM TERMINAL.
I>


 ENTER CONVERSIONAL MODE FOR DATA INPUT



 INPUT NAME OF FILE DATA IS TO BE WRITTEN TO.
 HIT A CARRIAGE RETURN IF YOU DO NOT WANT THIS FILE.
I>DOOREX3

 INPUT A QUESTION MARK (?) IF MORE INFORMATION IS NEEDED

 INPUT HEADING (HDG):
I>     E X A M P L E   P R O B L E M   T H R E E

 INPUT PROGRAM CONTROL (FLAG1,FLAG2,FLAG3,FLAG4,FLAG5,PC,COST):
I>0,1,1,0,0,0,0

 INPUT GEOMETRY (TOTIM,H,EL,FPRES,TD,PG,TG,ICODE(I), WHERE I=1,2,3,4):
I>4126,10,12,343.2,4.69,110.3,68.1,0,0,0,0

 INPUT STRENGTH PARAMETERS (FDY,TS,SN,DH,DEL,MU,EC):
I>48000,0,3,0,0,3,0

 PANEL PROPERTIES (ZHOR,ZVER,IAVG,WDR):
I>3.67,1.42,9.72,7368

 INPUT NAME OF FILE FOR OUTPUT TO BE WRITTEN TO.
 HIT A CARRIAGE RETURN IF OUTPUT TO TERMINAL
I>DOOROT3
      .086 CP SECONDS EXECUTION TIME.
```

```
C>OLD,DOOROT3
C>LIST


     E X A M P L E   P R O B L E M   T H R E E

        BLAST WALL HEIGHT          10.00  FT
        BLAST WALL LENGTH          12.00  FT

        DURATION OF LOAD         4.69000  MSEC

        FICTITIOUS PEAK PRESSURE          343.20  PSI
        EFFECTIVE IMPULSE                4126.00  PSI-MSEC

       FS DYNAMIC         48000.00  PSI
       PLATE THICKNESS        0.00  IN
       SUPPORT CODE           3.00
       DOOR HEIGHT            0.00  FT
       DOOR LENGTH            0.00  FT
       PLASTICITY (MU)        3.00
       HORIZONTAL Z           3.67  IN3/IN
       VERTICAL Z             1.42  IN3/IN
       I AVERAGE              9.72  IN4/IN
       DOOR WEIGHT         7368.00  LBS



     HEIGHT     120.00   IN    LENGTH      144.00   IN

  POSITIVE VERTICAL MOMENT      68160.00  IN-LBS/IN WIDTH
  NEGATIVE VERTICAL MOMENT      68160.00  IN-LBS/IN WIDTH
  POSITIVE HORIZONTAL MOMENT   176160.00  IN-LBS/IN WIDTH
  NEGATIVE HORIZONTAL MOMENT   176160.00  IN-LBS/IN WIDTH

  SUPPORT ON  3 SIDES


  LOCATION YIELD LINE LENGTH           72.00  IN
  LOCATION YIELD LINE HEIGHT           60.69  IN
  ULTIMATE LOAD CAPACITY  RU        185.0344  PSI
  SHEAR LOAD AT HORIZ SUPPORT       10869.66  LB/IN WIDTH
  SHEAR LOAD AT VER SUPPORT          6738.18  PSI
```

LOAD MASS FACTOR	.6568	
MASS	724.79	LB-MSEC2/IN/IN2

FIRST YIELD POINT AT PT3		
ELASTIC LIMIT RE PSI	65.20	
ELASTIC DEFLECTION XE	.2967	IN
SECOND YIELD AT PT 2		
ELASTO PLASTIC LIMIT	93.35	PSI
ELASTO-PLASTIC DEFLECTION	.6349	IN
ULTIMATE RESISTANCE	185.03	PSI
PLASTIC DEFLECTION	2.1888	IN

ULTIMATE RESISTANCE RU	185.03	PSI
ELASTIC DEFLECTION LIMIT XE	1.6455	IN
STIFFNESS KE	112.45	LB/IN/IN2
ALLOWABLE MAX DEFLECTION	4.9364	IN

MASS	724.795	LB-MSEC2/IN/IN2
LOAD	343.200	PSI
DURATION	4.690	MSEC
RESISTANCE	185.034	PSI
STIFFNESS	112.450	LB/IN/IN2
GAS PRESSURE	110.30	PSI
DURATION	68.10	MSEC

MEMBRANE YIELD DEFLECTION	3.796454	IN
ELASTIC DEFLECTION LIMIT	1.645479	IN
MAXIMUM DEFLECTION	3.665975	IN
NATURAL PERIOD	15.951698	MSEC
TIME TO MAXIMUM DEFLECTION	9.037378	MSEC
DURATION/NATURAL PERIOD	4.269138	

```
LOAD/RESISTANCE                 1.854790
CALCULATED DIF FOR FDY          1.447980
TIME TO YIELD                   3.28172933  MSEC

C>
```

APPENDIX D: SAMPLE DATE GUIDE

CSDOOR Data Format

FILENAME =

	HEADING (JOB DESCRIPTION)							
Line 1								
	OPTIONS							
	FLAG1	FLAG2	FLAG3	FLAG4	FLAG5	PC		COST $/lb (Default = 0.60)
	0 = Analyze 1 = Optimize	0 = Calc. Blast Load 1 = Input p-t History	0 = Input Door TS 1 = Input Door Z	0 = Omit Grid 1 = Calculate Grid	0 = No Opening in Door 1 = Opening in Door	0 = Standard Printout 1 = Print Response-Time History		
Line 2								
	WLB lb	ANUM (Default = 1.0)	RLOD (Default = 1.0)	CASE	APAMB, psia (Default = 14.69)	TAMB, °C (Default = 20.0)	ALTKFT 10^3 ft	
If FLAG2 = 0, Line 3								
	RA ft	H ft	EL ft	HLIT ft	ELLIT ft	AV ft^3	AC ft^2	ICODE F R L R
If FLAG2 = 0, Line 4a								
	TOTIM psi-msec	H ft	EL ft	PRES psi	TO msec	PG psi	TG msec	ICODE F R L R
If FLAG2 = 1, Line 4b								
	FDY psi	TS in.	SN	DH ft	DEL, ft If ≠ EL	U	E, psi (Default = 29,000,000)	
Line 5								
	ZHOR $in.^3/in.$	ZVERT $in.^3/in.$	IAVG $in.^4/in.$	WDR lb				
If FLAG3 = 1, Line 6								
	H2 ft	WT ft	B ft	REA lb/in.	RD1 psi	H1 ft		
If FLAG5 = 1, Line 7								

NOTE: For time-sharing applications, all entries (including 0) must be made for each required line of data.
Optimization cannot be used if FLAG3 = 1 or FLAG5 = 1.
Door and wall are synonymous when DH = H and DEL = EL.
FLAG5 = 1 can only be used when SN = 2, 3, or 4.

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

	Title	Date
Technical Report K-78-1	List of Computer Programs for Computer-Aided Structural Engineering	Feb 1978
Instruction Report O-79-2	User's Guide: Computer Program with Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Mar 1979
Technical Report K-80-1	Survey of Bridge-Oriented Design Software	Jan 1980
Technical Report K-80-2	Evaluation of Computer Programs for the Design/Analysis of Highway and Railway Bridges	Jan 1980
Instruction Report K-80-1	User's Guide: Computer Program for Design/Review of Curvilinear Conduits/Culverts (CURCON)	Feb 1980
Instruction Report K-80-3	A Three-Dimensional Finite Element Data Edit Program	Mar 1980
Instruction Report K-80-4	A Three-Dimensional Stability Analysis/Design Program (3DSAD)	
	Report 1: General Geometry Module	Jun 1980
	Report 3: General Analysis Module (CGAM)	Jun 1982
	Report 4: Special-Purpose Modules for Dams (CDAMS)	Aug 1983
Instruction Report K-80-6	Basic User's Guide: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Instruction Report K-80-7	User's Reference Manual: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Technical Report K-80-4	Documentation of Finite Element Analyses	
	Report 1: Longview Outlet Works Conduit	Dec 1980
	Report 2: Anchored Wall Monolith, Bay Springs Lock	Dec 1980
Technical Report K-80-5	Basic Pile Group Behavior	Dec 1980
Instruction Report K-81-2	User's Guide: Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (CSHTWAL)	
	Report 1: Computational Processes	Feb 1981
	Report 2: Interactive Graphics Options	Mar 1981
Instruction Report K-81-3	Validation Report: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Feb 1981
Instruction Report K-81-4	User's Guide: Computer Program for Design and Analysis of Cast-in-Place Tunnel Linings (NEWTUN)	Mar 1981
Instruction Report K-81-6	User's Guide: Computer Program for Optimum Nonlinear Dynamic Design of Reinforced Concrete Slabs Under Blast Loading (CBARCS)	Mar 1981
Instruction Report K-81-7	User's Guide: Computer Program for Design or Investigation of Orthogonal Culverts (CORTCUL)	Mar 1981
Instruction Report K-81-9	User's Guide: Computer Program for Three-Dimensional Analysis of Building Systems (CTABS80)	Aug 1981
Technical Report K-81-2	Theoretical Basis for CTABS80: A Computer Program for Three-Dimensional Analysis of Building Systems	Sep 1981
Instruction Report K-82-6	User's Guide: Computer Program for Analysis of Beam-Column Structures with Nonlinear Supports (CBEAMC)	Jun 1982
Instruction Report K-82-7	User's Guide: Computer Program for Bearing Capacity Analysis of Shallow Foundations (CBEAR)	Jun 1982

(Continued)

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Concluded)

	Title	Date
Instruction Report K-83-1	User's Guide: Computer Program With Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Jan 1983
Instruction Report K-83-2	User's Guide: Computer Program for Generation of Engineering Geometry (SKETCH)	Jun 1983
Instruction Report K-83-5	User's Guide: Computer Program to Calculate Shear, Moment, and Thrust (CSMT) from Stress Results of a Two-Dimensional Finite Element Analysis	Jul 1983
Technical Report K-83-1	Basic Pile Group Behavior	Sep 1983
Technical Report K-83-3	Reference Manual: Computer Graphics Program for Generation of Engineering Geometry (SKETCH)	Sep 1983
Technical Report K-83-4	Case Study of Six Major General-Purpose Finite Element Programs	Oct 1983
Instruction Report K-84-2	User's Guide: Computer Program for Optimum Dynamic Design of Nonlinear Metal Plates Under Blast Loading (CSDOOR)	Jan 1984

LMED

-8